INSTRUMENTS AND CONTROL SYSTEMS

INCLUDING: INSTRUMENT MANUFACTURING • JOURNAL OF THE SCMA • SIMULATION COUNCIL NEWS LETTER

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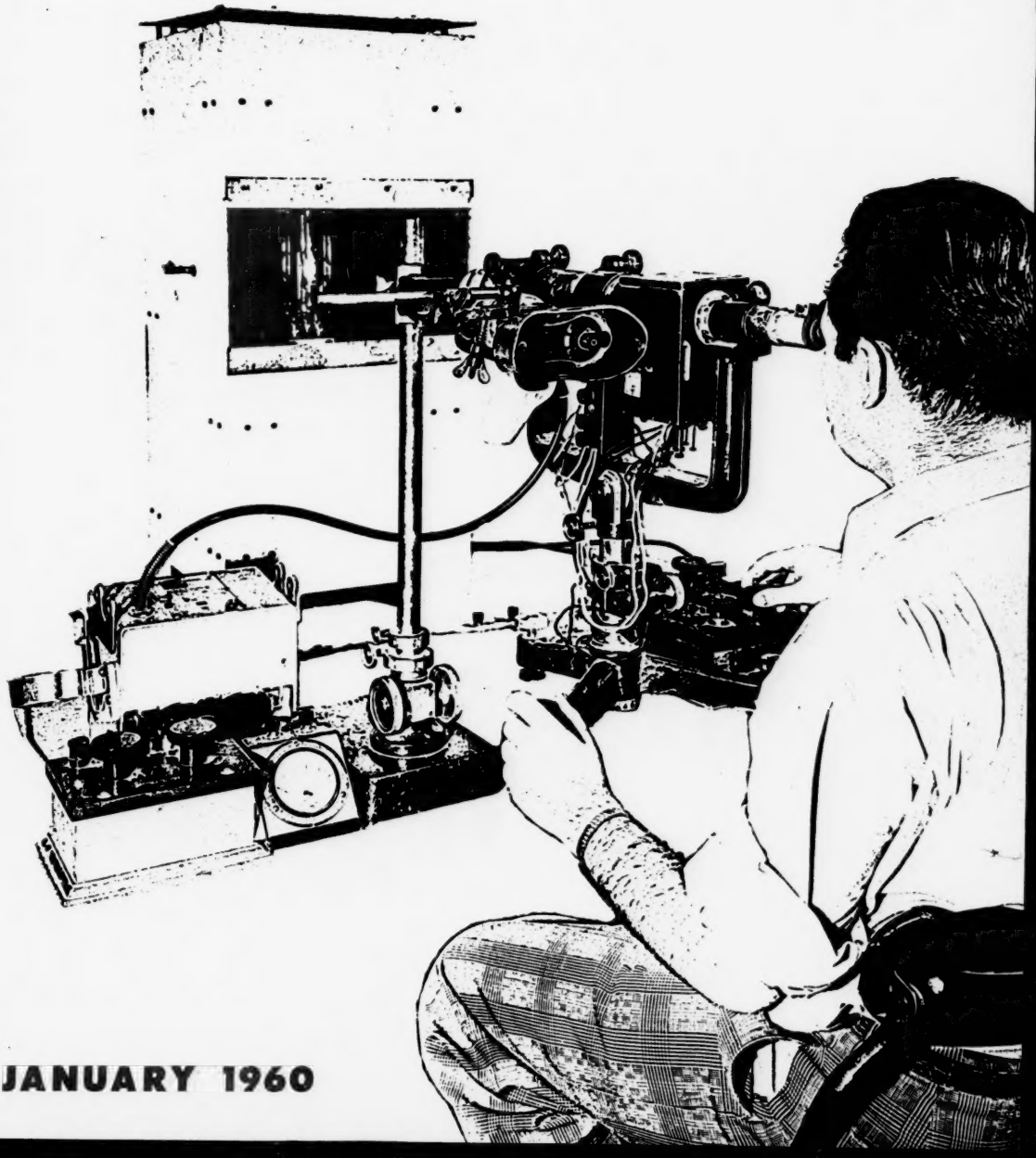
THIS PRINTING: 35,000



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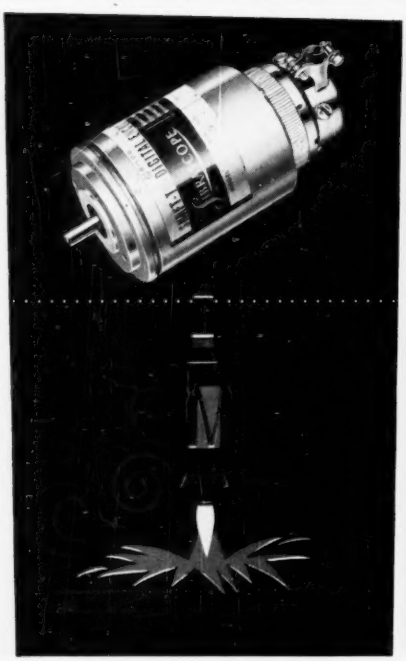

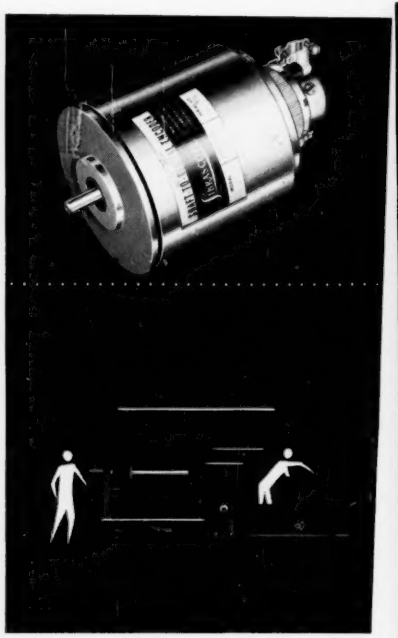

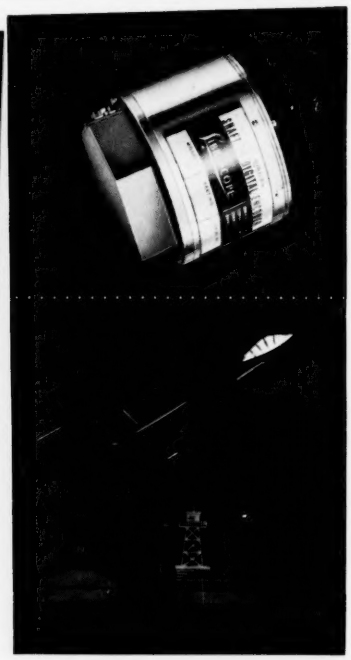

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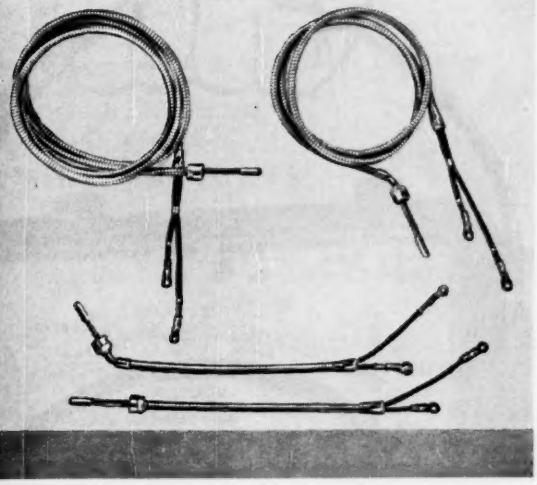

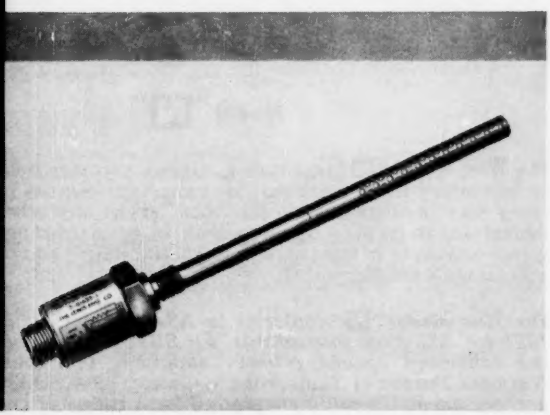

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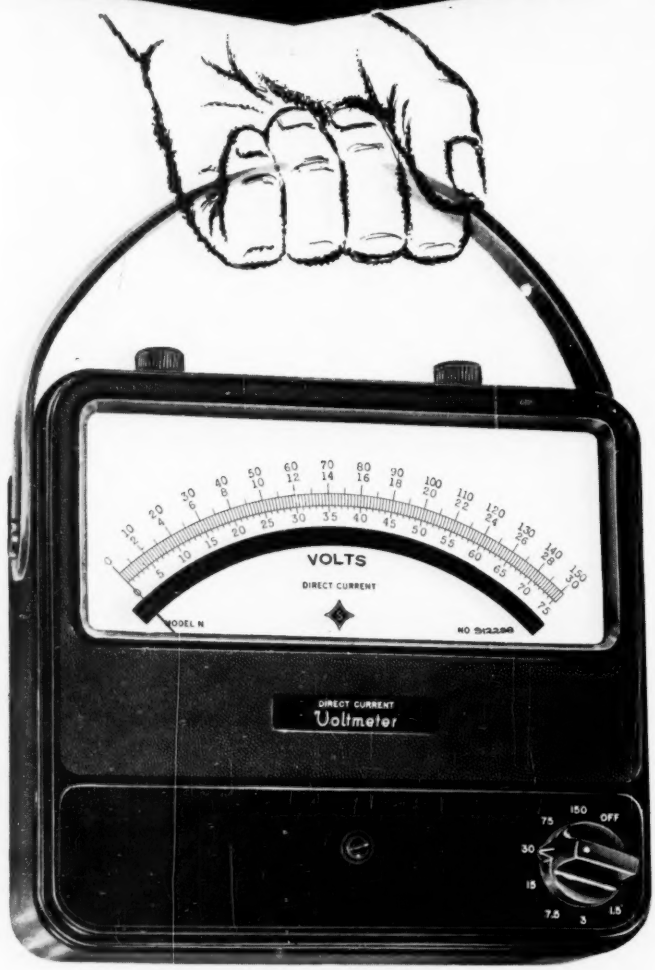

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A *New* HIGH in accuracy, resolution, and stability.

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Availability: 1 to 8 ranges completely switch-controlled and self contained.

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Case: Black moulded bakelite with leather carrying handle. Size 7½" x 6¾" x 3½".

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VOLUME 33
NUMBER 1

JANUARY
1960

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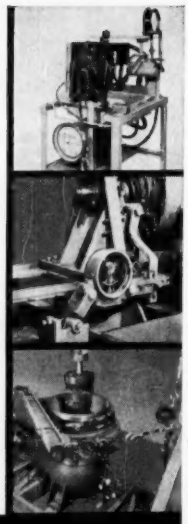

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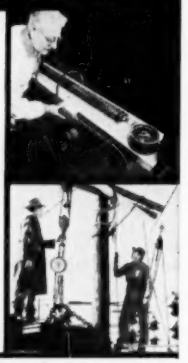

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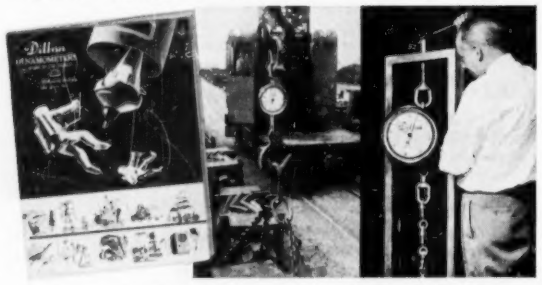

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from
Instrument Calibration
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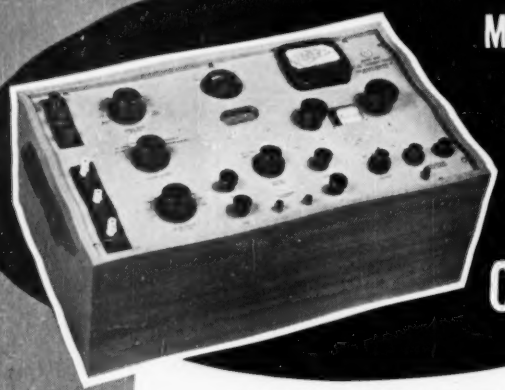

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I&CS LETTERS TO THE EDITOR

Editor, I&CS:

Congratulations on a magnificent job of face-lifting and revising of your magazine. It was commented on favorably by many of our faculty, none of whom are instrument people except me.

I am in a predicament as I wish to re-subscribe, but I have now gone into teaching where the dollars are fewer. Do you follow the policy of other magazines and offer an educational rate to full-time educators?

Benjamin E. DeRoy, P. E.
Lecturer
The Community College & Technical Institute of Temple University
Philadelphia, Penna.

This man steps up in service to his country—and down in income. A sorry state of affairs!

Editor, I&CS:

Enclosed is a small list of new subscriptions (17) to INSTRUMENT AND CONTROL SYSTEMS . . . I obtained the 17 subscriptions in one day.

Both I and others have been extremely impressed with your excellent editorials on instruments and education.

Wm. H. Haney,
Los Angeles, Calif.

Editor, I&CS:

I think what you are doing (Pittsburgh "Modern Physics" high-school course) is most worthwhile and you should be congratulated on having not only talked about it, but putting it to work.

Thomas Meloy
Melpar, Inc.
Falls Church, Va.

Editor, I&CS:

I would like to obtain a copy of the editorial "Report on Public High School Course in Modern Engineering Physics." I teach physics and chemistry in the college and high school in Elgin.

R. H. Jensen
Elgin Community College
Elgin, Ill.

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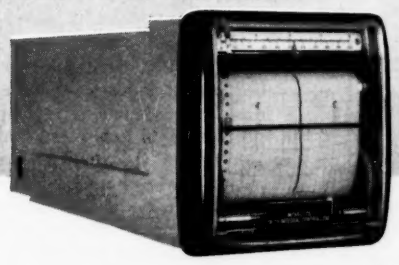

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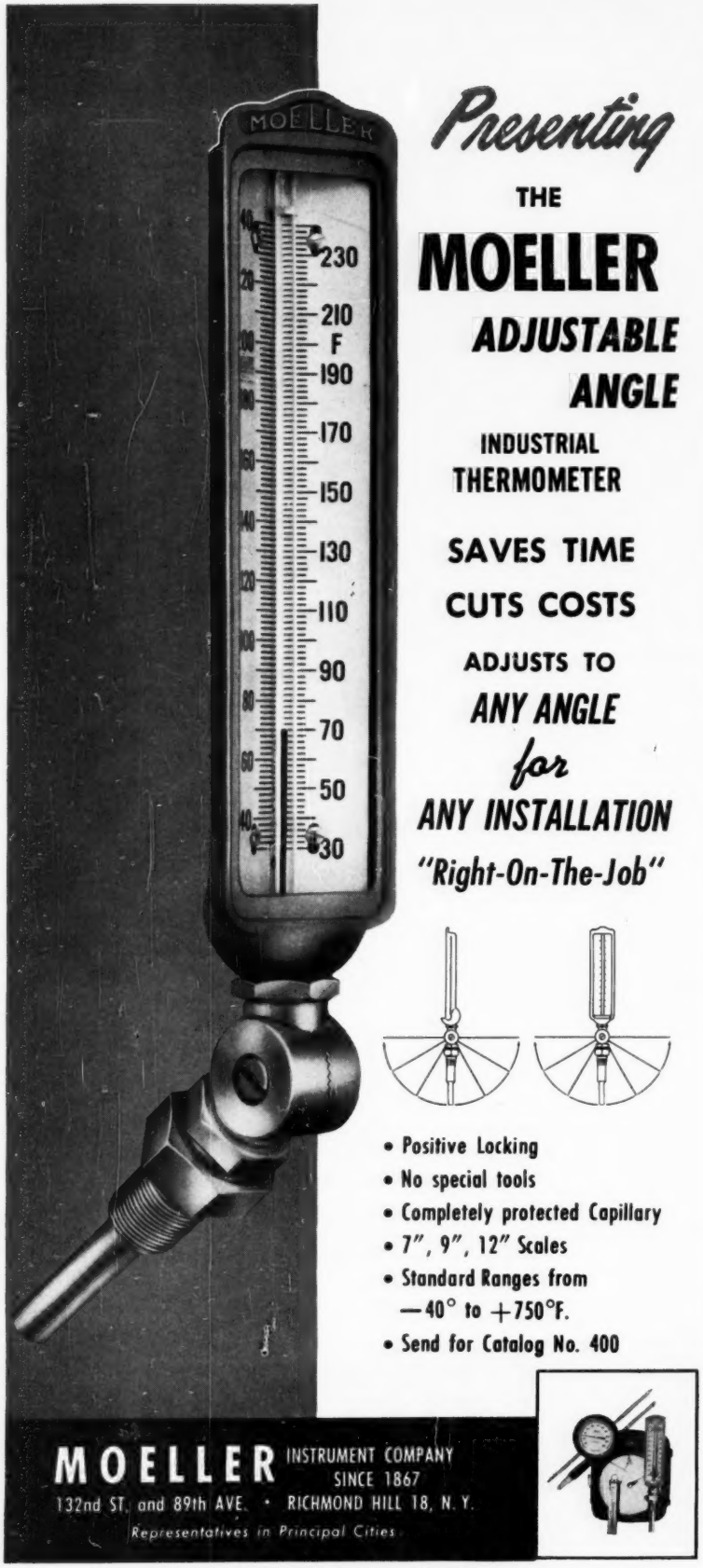

CIRCLE 8 ON READER-SERVICE CARD

LETTERS—CONTINUED

Editor, I&CS:

First of all it seems a certainty to me that any program which brings together high school students and men of the caliber mentioned in this report [Modern Engineering Physics] would be of great value. If such lectures were available here, I would go myself! It is also probably of more value than some might realize for the scientists and engineers to learn again at first hand of the enthusiasm and ability of high school age students.

I notice that the extra work involving instruments was a supplement to and not a replacement for a physics course. Thus the question is not what kind of physics course should be taught but rather what kinds of supplementary programs should be considered. You would know better than I how likely it is that the program you have developed in Pittsburgh could be generalized to other localities. I would guess that most of the criticisms leveled against this program have not meant to condemn the specific activities reported but rather to predict that such advantageous conditions are so unlikely to be available that the program cannot be taken as a model for general distribution.

Beyond this it would seem to me that the editorial, *A Threat to American Education and the Instrument Industry*, is an unfortunate one.

David A. Page, Director
University of Illinois
Urbana, Illinois

Editor, I&CS:

I have been reading about your part in establishing the curriculum in automation at a Pittsburgh High School. We are interested in this general area. Do you have any suggestions on text books?

Kenneth Lea
Columbus, Ohio

The texts were selected by the course instructor, who attended an instrument-manufacturers' school to obtain some insight into the field. Mr. Replogle, the course instructor answers as follows:

The books we have selected have worked out very nicely to date both in level and content. The emphasis on electronics is heavy, and after a careful survey of many available electronics books the one selected was "*Electronic Circuitry for Instruments & Equipment* by M. Aronson, Instruments Publishing Company. This is,

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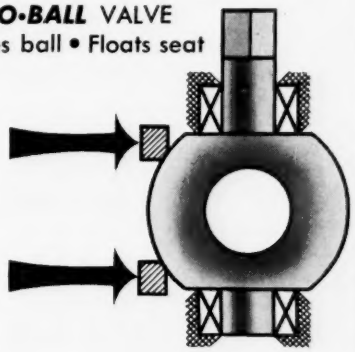

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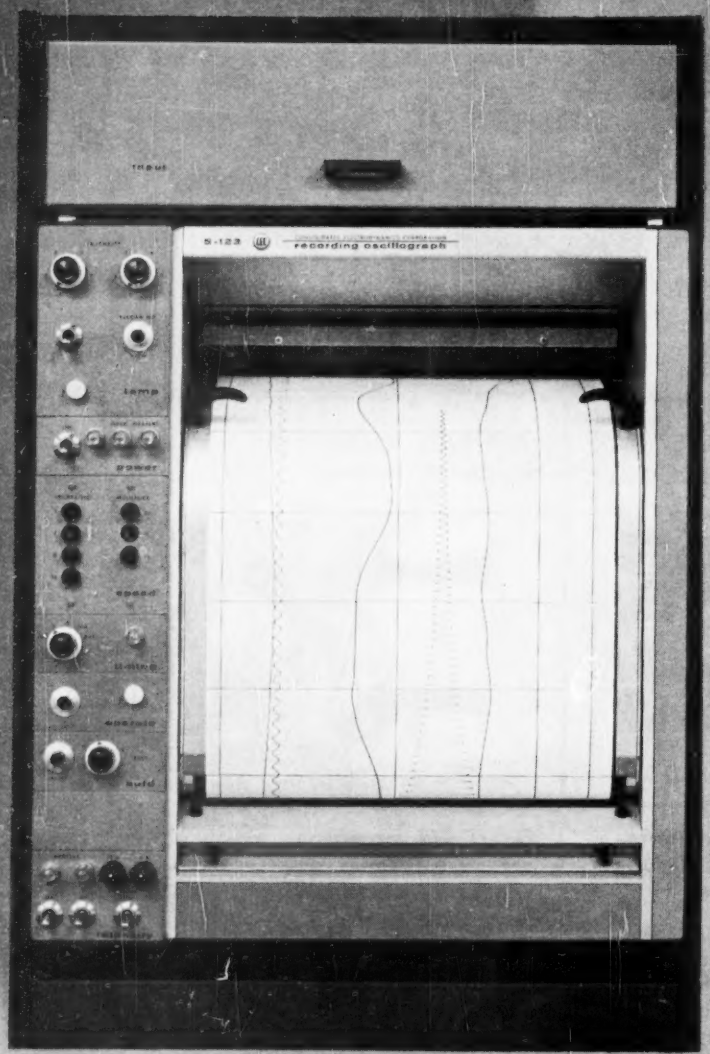
5-123

accessibility



Model 5-123, the new look

in oscillography from:

Electro Mechanical Instrument Division

CEC

LETTERS —CONTINUED

in my opinion, the best book available for beginners.

The students are preparing themselves for intensive computer studies by learning digital codes. The book *Digital Techniques* by M. Klein is not too complicated for high-school seniors and gives them the codes and the electronic circuitry that they are also studying.

For specific measurement aspects in temperature, pressure, etc., the *Handbook of Measurement and Control* by M. F. Behar is used as reference, with manufacturers' literature also used heavily.

The students are learning at a rate that surprises even me.

N. Replogle
Allegheny High School
Pittsburgh, Pa.

Editor, I&CS:

Motorola Systems Research Laboratory is undertaking to study the characteristics available in industrial type instruments in view of present and future needs. It is believed that a first step should be a thorough and comprehensive analysis of existing equipments . . . If your organization has compilations or knows of any references relative to this study we shall be most anxious to hear of them.

Alan R. Shapiro
Motorola Systems
Research Laboratory
Riverside, Calif.

Every issue of INSTRUMENTS AND CONTROL SYSTEMS has much on this subject. Since 1958, each issue has been devoted to a specific subject. Thus transducers for strain were covered in the March (1958) issue, nuclear instruments in April, recorders in May, weight in December, etc.

Our several books also cover transducers. The chapter entitled "Scientific and Industrial Instruments" in the book ELECTRONIC CIRCUITRY FOR INSTRUMENTS AND EQUIPMENT covers all basic transducers. Similarly, strain transducers are covered in the book STRAIN GAGE INSTRUMENTATION. Lists of transducers also appear in the 1960 BUYERS GUIDE (Part II of October issue).

Editor, I&CS:

Your book *Electronic Circuitry for Instruments and Equipment* arrived today.

You have done very well in con-

← CIRCLE 10 ON READER-SERVICE CARD

taining so much information without dependence on mathematics above the laymen level.

You have laid it out logically, commencing with the electrical nature of all matter and the circuit elements from which everything in electricity, radio and electronics may be derived. You cover tubes used with such circuit elements and wind up with the highest order of their application . . . namely military electronics.

Samuel Freedman
Gen. Manager
Chemalloy Electronics
Santee, Calif.

Editor, I&CS:

Starting in the July, 1951 issue of *Instruments* there was a series of articles on "Instrument Electronics." Would it be possible to get a complete set of that series, including the questions and answers that were used with each topic? I am taking a course in instrumentation, and this will help me with electronics.

Lowell D. Keifer
Borger, Texas

The entire series, with 458 multiple-choice questions and answers is available in the text *ELECTRONIC CIRCUITRY FOR INSTRUMENTS AND EQUIPMENT* by M. Aronson, Instruments Publishing Company, $2.00. More than 10,000 copies have been sold to date, making this one of the most popular basic electronics texts available.

Editor, I&CS:

I have just received the current *INSTRUMENTS AND CONTROL SYSTEMS BUYERS' GUIDE* and found it quite absorbing. I consumed two hours merely reviewing it so that I may make good use of it in the future.

I hope that your publication *INSTRUMENTS AND CONTROL SYSTEMS* maintains its present high standards. I do find one minor (?) fault with *INSTRUMENTS AND CONTROL SYSTEMS.* I feel your ELECTRONIC CIRCUITRY column leans too hard in the direction of semi-conductor devices. I find each circuit has something new, and is frequently helpful, but I still do use and frequently design circuits and equipment involving vacuum tubes.

Norman J. Thompson
Battelle Memorial Institute
Columbus, Ohio

All tube circuits this month!

CIRCLE 11 ON READER-SERVICE CARD →

5-123 versatility

ANOTHER CEC FIRST – TYPE 5-123, THE RECORDING OSCILLOGRAPH SPECIFICALLY DESIGNED FOR RACK MOUNTING.

The new CEC 5-123 is the last word in mounting versatility. Rack it vertically for stand-up visibility... lay it horizontally for table-top operation... bench mount it. All operations, including galvanometer insertion and adjustment, and routine maintenance are performed from the *front* of the instrument, allowing you to mount it side-by-side with other instrumentation or stack it flush top and bottom.

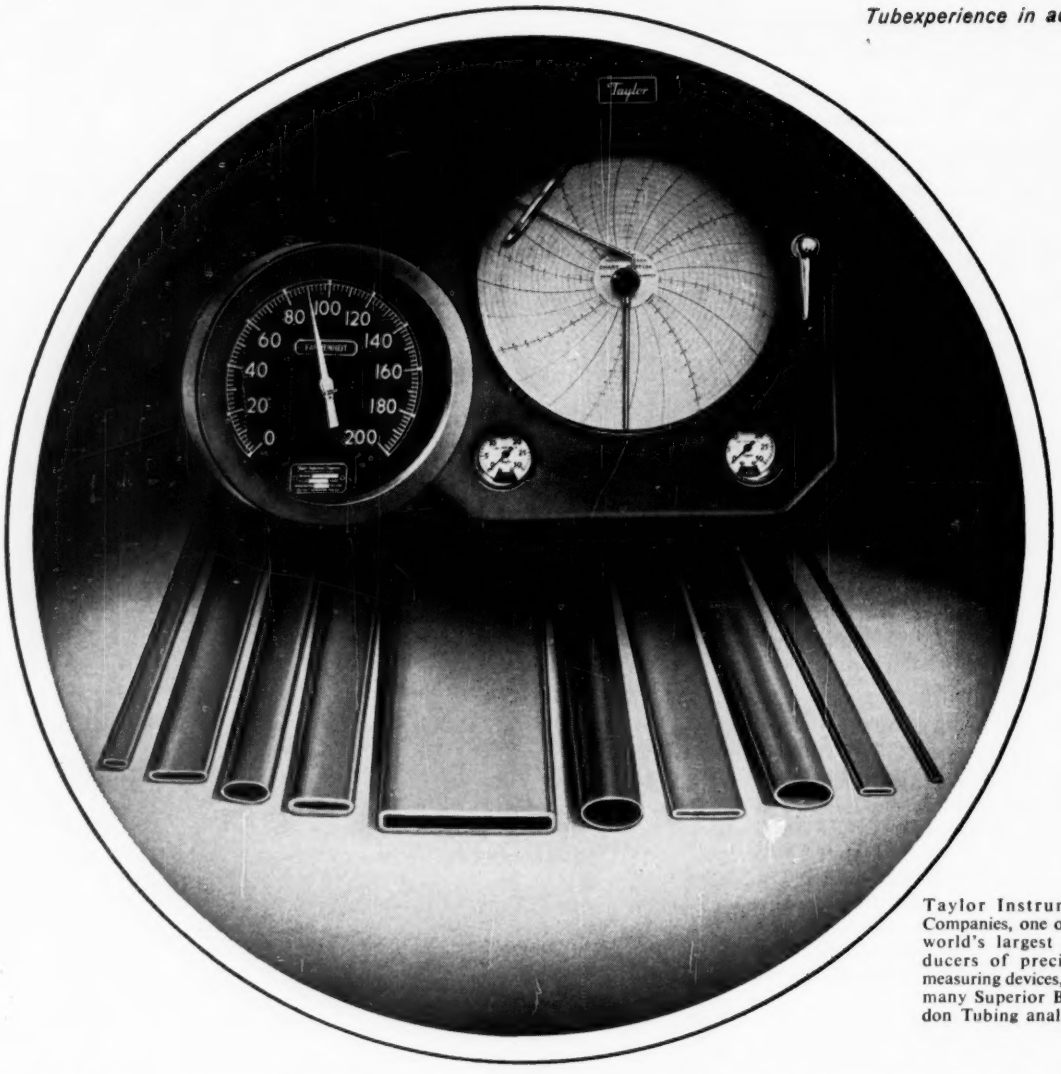
Pushbutton controls provide instantaneous speed changes from 0.1 to 160 ips. Construction is entirely of modular units, each of which can be removed, replaced, or interchanged between instruments without extensive disassembly. The self-contained magazine puts 36 to 50 visible data channels at your fingertips within seconds without chemical processing – using CEC's exclusive "Dataflash" technique.

Electro Mechanical Instrument Division **CEC**

CONSOLIDATED ELECTRODYNAMICS / pasadena, california

For complete information on this new oscillograph, contact your nearest CEC sales and service office, or write for Bulletin CEC 1623-X1.

Tubexperience in action



Taylor Instrument Companies, one of the world's largest producers of precision measuring devices, uses many Superior Bourdon Tubing analyses.

℞ for accurate indication of pressure and temperature: Bourdon Tubing by Superior

Bourdon tubes with consistent spring rate and minimum set, drift and hysteresis are essential to precision measurement of pressure in modern indicating, recording and controlling instruments. The tubing from which they are made must be free of inclusions and seams, carburization or decarburization, rough or corroded surfaces, and variations in wall thickness. Superior Bourdon Tubing has the extra qualities that permit interchangeability of Bourdon elements in the field with maximum ease, simplify range changes, require only linkage adjustment.

Typical of the care exercised in the manufacture of Superior Bourdon Tubing is the use of weight control to check tubing dimensions. This fast, precision method of checking average wall or ID enables us to provide tubing with unusually high overall uniformity. No matter how many Bourdon elements you make from Superior tubing, you get a uniform deflection rate in every case.

Superior offers a wide range of analyses, including strain-hardened, precipitation-hardened and heat-treatable materials for the fabrication of Bourdon Tube elements. Write for a copy of Bulletin 41, giving detailed information. Write Superior Tube Company, 1968 Germantown Ave., Norristown, Pa.

Superior Tube

The big name in small tubing

NORRISTOWN, PA.

All analyses .010 in. to ⅝ in. OD—certain analyses in light walls up to 2½ in. OD

West Coast: Pacific Tube Company, Los Angeles, California • FIRST STEEL TUBE MILL IN THE WEST

CIRCLE 12 ON READER-SERVICE CARD

LETTERS—CONTINUED

Editor, I&CS:

Enclosed you will find a check for my renewal. I debated a great deal about renewing, and perhaps my reasons may help in a small way determine your policy.

I consider my work to be best described as Gas Measurement Engineering. I am now in Research and Development, a newly formed group to work in that field. I also teach Physics at the University of Omaha, College of Adult Education. Have been on their staff, now, for twelve years.

Your magazine has proved exceedingly valuable. I teach most of Electricity directly from Mr. Aronson's "Instrument Electronics" series of some years ago—there has never been a better text produced, to my knowledge, geared to practical applications, which is what adults come for.

The articles on Bureau of Standards, have been used a great deal. Other physics and measurement articles have found a great use.

Now for the criticism: I wonder what percentage of your readers can ever use the vast material on computers? Some of your recent issues include plenty of material that can be used by a practical person; entirely too much is slanted to the small group of computer experts. Our other engineers except of course the Datatron section, feel the same way.

Paul W. Nelson
Omaha, Nebr.

Editor, I&CS:

We are writing to you in regard to your search for a proportional type liquid level controller to control flow into tank of filling machine. You further specify that sensing element must be small and sterilizable for milk, with other liquids ranging from water-base solutions to oils.

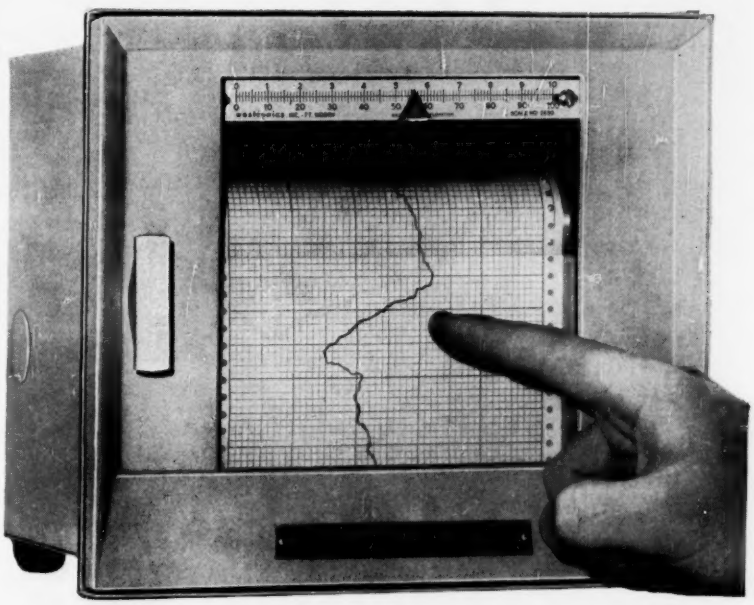
We wish to suggest as a possibility the use of our Data Unit, Model #902-1. This incorporates our T-42 Ionization Transducer, which is a unique device capable of converting extremely small capacity change directly into a proportional dc voltage output. The Delta Unit will provide a full range signal swing of ±30 volts.

I would visualize using the Delta Unit with a capacity sensor, the ground side of which may constitute the walls and bottom of your tank. A metal rod (preferably coated with dielectric plastic) may be inserted into the tank, providing it is isolated from the tank surface. The level of

SMALL SIZE...

BIG

PERFORMANCE



westronics 5-inch chart potentiometer recorders

combine the quality and features of a large recorder in a small package

THREE MODELS TO CHOOSE FROM:

MODEL S5—Single Pen with one second full scale pen travel, continuous electronic standardization.

MODEL D5—Dual Pen with two pens traveling the full five inches of chart paper, requires only 9⅝" x 8½" panel space.

MODEL M5—Multipoint, scans, samples and prints 12 points on 5-inch chart paper with accuracy of ±0.5% full scale.

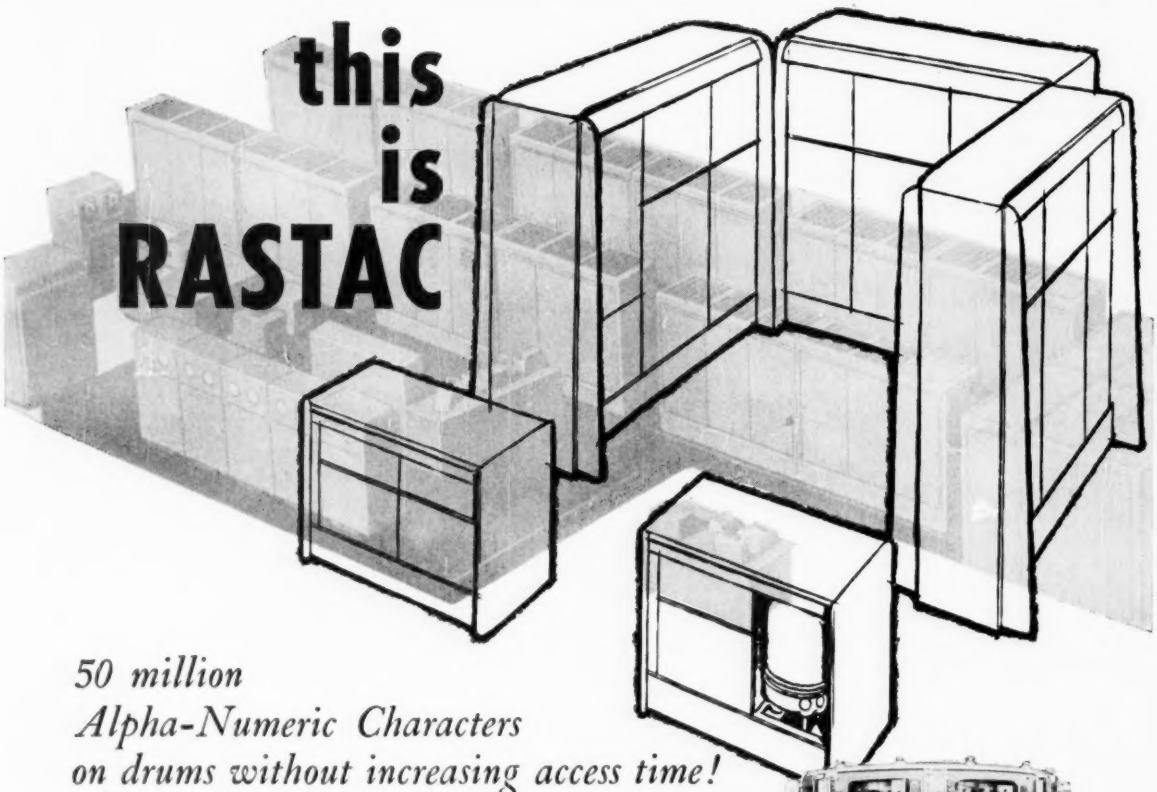
Westronics manufactures both 5 inch and 11 inch recorders . . . order today!

westronics®

WESTRONICS, INC.
3805 AIRCRAFT
FORT WORTH, TEXAS

CIRCLE 13 ON READER-SERVICE CARD

this is RASTAC



50 million Alpha-Numeric Characters on drums without increasing access time!

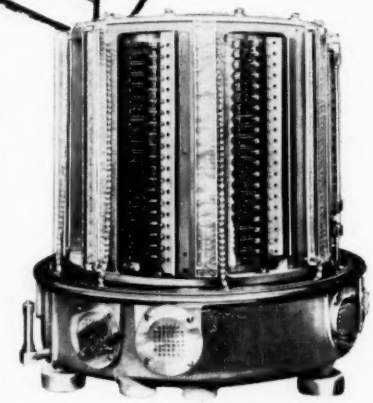
LFE's RASTAC means Random Access Storage and Control in a big way. In general-purpose digital computer applications, it provides mass data storage on an on-line basis. Thus, RASTAC eliminates the "hang-ups" encountered while the computer is searching for data on cards or tape. *Average random access time is only 1/6 of a second, regardless of the size of the system!*

A complete LFE RASTAC System may include from one to thirty-three high density magnetic file drums (LFE Type HD), plus three cabinets of control and power supply elements. So RASTAC is actually a building-block system of reliable magnetic modules.

A RASTAC System can be assembled as a one drum unit with a storage capacity of 1.5 million characters. Or the maximum RASTAC is available with 33 HD drum units for a total storage capacity of almost 50 million characters.

But regardless of the number of drums in use, LFE's RASTAC system always offers an average random access time of 1/6 of a second.

RASTAC is a truly versatile system. In addition to normal on-line operations in conjunction with the Computer, it may also be used independently as a file with the appropriate input and output stations. When used on-line RASTAC may be also equipped with facilities for independent operation during computer down time.



RASTAC can be used in conjunction with any *general purpose digital computer.*

We suggest you consider the RASTAC System if you require fast access to mass data storage. Descriptive literature is available on request. Write to Department **1-1**

Leadership From Experience

LABORATORY FOR ELECTRONICS, INC.
Computer Products Division
1079 COMMONWEALTH AVENUE, BOSTON

CIRCLE 14 ON READER-SERVICE CARD

LETTERS —CONTINUED

the liquid which constitutes dielectric change will then provide an output voltage proportional to the level. In order to use it for other liquids, the same set up can be used but the output signal calibration would be different. The Delta Unit has been successfully used in similar liquid level applications.

Bert Schwarzschild
The Decker Corporation
West Coast Engineering Division
San Francisco, Calif.

Editor, I&CS:

Reader A-326 has made an inquiry about a rotary type humidifier.

Enclosed is descriptive literature covering the Amco Model 35 Humidifier and the Amco No. 6 atomizer type humidifier which may be helpful to your reader.

American Moistening Company
A. A. St. Germain,
Providence, R. I.

Editor, I&CS:

Subject: Reader Inquiry A-334

Will you please forward the enclosed literature along to the Engineer who has inquired about the heat flow meter. It gives data on heat flow elements which operate up to only 300°F. However we are developing heat flow elements which will go up to 1500°F.

Furthermore, we have several types of secondary elements such as meters and recorders to go with the primary heat flow elements.

D. I. Steele
National Instrument Laboratories, Inc.
Washington, D. C.

READER INQUIRIES

Company Identification

Government agency seeks present address of Electro-Physical Labs., Inc. (formerly of New York City), manufacturers of a 4-channel electroencephalograph (Model E4W119). A-603

Permanent Magnets

Manufacturer of gage accessories seeks permanent magnets ⅛" x ⅛" x ¼" (or ½") long. A-602

Manganin Resistors

Instrument importer in Sweden seeks source of supply for manganin resistors rated @ one ma, for 0.5 Mohm, and one precision-type rated 10^{-5} ohms. A-601

Dimensions
3.87" x 1.87" x 1.16"
Statham
MODEL CA 9 STRAIN GAGE SIGNAL AMPLIFIER PROVIDES BIG-INSTRUMENT RELIABILITY IN 8-OUNCE PACKAGE
Statham has drastically reduced the size and weight of strain gage signal amplifiers. The Statham CA 9 is completely transistorized, weighs only 8 ounces, is less than 8½ cubic inches in size, and yet is more reliable in adverse environments than larger and heavier amplifiers.
This tiny instrument provides for total utilization of low-level signals and ensures the precision required in current aircraft and space vehicle applications. For complete specifications, write for Data File ICS-995-1.
For leadership in measurement
STATHAM INSTRUMENTS, INC.
12401 W. Olympic Blvd.
Los Angeles 64, California
CIRCLE 15 ON READER-SERVICE CARD

YOUR *FISHER/MAN* STANDS BEHIND THIS

FOR Inherent Accuracy–Power–Speed–and Stability

FISHER TYPE 470 P.O.P.

- Delivers same power in either direction at any point of the stroke.
- No air set required—utilizes clean, noncorrosive air or gas up to 150 psi.
- Adaptable to virtually all types of valve bodies including Butterfly valves.
- Easily reversible actuator can be changed in the field.

Available with large variety of accessories such as: spring return, side mounted handjack, hydraulic snubber and pneumatic safety return devices. Write for Bulletin E-470.

Type 470 P.O.P. With Fisher Bodies				
Cylinder Size, Inches	Yoke Boss Size, Inches	Valve Body Size, Inches	Stem Size, Inches	Allowable Stem Force, Lbs.
4¾	2⅛	½—1½	⅜	1,500
	2 13/16	2—4	½	*
	3 9/16	5—8	¾	*
6⅛	2 13/16	2—4	½	2,500
	3 9/16	5—8	¾	*
8½	3 9/16	5—8	¾	5,000
10¾	5	10—16	1	8,000
13	5	10—16	1¼	12,000

*Limitation with these stems is dependent upon the maximum force available from each cylinder.

IF IT FLOWS THROUGH PIPE ANYWHERE IN THE WORLD . . . CHANCES ARE IT'S CONTROLLED BY . . .

FISHER GOVERNOR COMPANY

Coraopolis, Pa. / Woodstock, Ontario / London, England

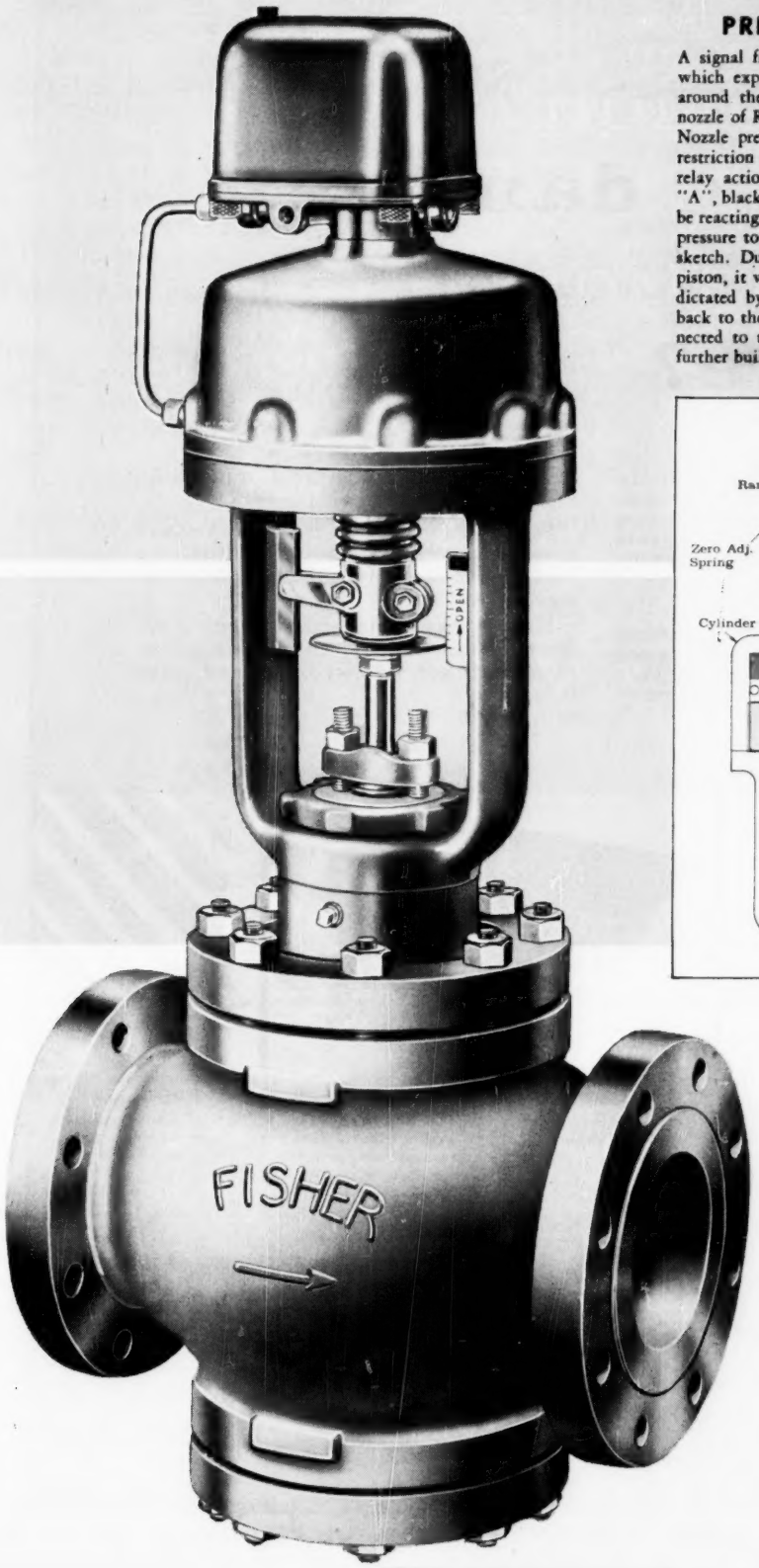
Main Office and Plant: MARSHALLTOWN, IOWA

FISHER® Control

SINCE 1880

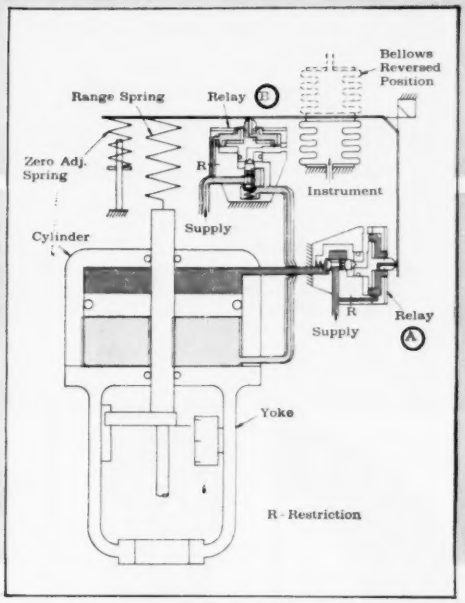
CIRCLE 16 ON READER-SERVICE CARD

PNEUMATICALLY OPERATED PISTON...



PRINCIPLE OF OPERATION

A signal from the controller is received by the bellows which expand to move the beam. The beam will pivot around the fixed point and simultaneously uncover the nozzle of Relay "B" and cover the nozzle of Relay "A." Nozzle pressure will increase in Relay "A" due to the restriction created by the beam over the nozzle. Through relay action, the air pressure to the top of the piston, "A", black in the sketch, will be increased. Relay "B" will be reacting to the change in beam position to decrease the pressure to the under side of the piston, "B", red in the sketch. Due to the unbalanced pressures acting on the piston, it will move down, changing the valve position as dictated by the controller. The piston movement is fed back to the beam by means of a range spring that is connected to the piston rod extension, thus preventing any further build-up of pressure in the cylinder.



Exterior view of high pressure actuator. Type 470 mounted on a Design "A" body.

CIRCLE 16 ON READER-SERVICE CARD

What's your tubing problem?

corrosion?
damage?
installation?
fire? cost?

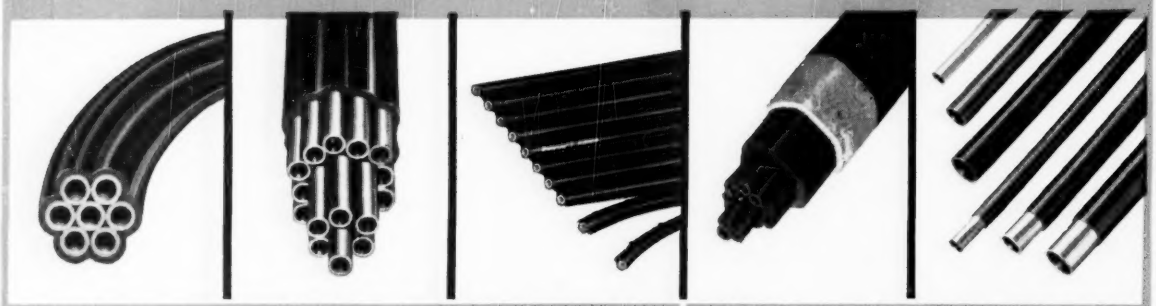
Wherever instrument tubing is used—be it refinery, natural gasoline plant, chemical, nuclear or food processing—Dekoron Tubing Products can help whip your ultimate twin problems of *maintenance-replacement expense and installation costs.*

Why?

First, because Dekoron Tubing products resist chemical attack and corrosion caused by moisture and industrial atmospheres. That means that once installed, Dekoron products are in to stay. You're not faced by perennial replacement and maintenance costs.

Second, the big savings in cost are yours in installation when you specify multiple-line Dekoron products—you install many instrument lines at once.

So if you have an instrument tubing problem of *any sort*, we probably have the answer *in stock*. If not, we can design and make it for you.



POLY-COR
From 2 up to 37 plastic tubes in plastic armor.

METL-COR
From 2 up to 19 copper or aluminum tubes in plastic armor.

RIBBON
M-Ribbon (metal) and P-Ribbon (plastic). 10 tubes in plastic sheath.

PROTECTO-PAC
Fire and impact resistant. Plastic tubes covered with plastic-asbestos-plastic armor.

SINGLE-LINE
Single steel, copper or aluminum tubes in plastic armor, or all-plastic tubing.

Dekoron® products
QUALITY • RESEARCH • SERVICE

SAMUEL MOORE & CO.
Dekoron Products Division
MANTUA, OHIO

AA-6682

CIRCLE 17 ON READER-SERVICE CARD

Logger survey made by INSTRUMENTS AND CONTROL SYSTEMS indicates that to date approximately 250 process logging systems have been installed, comprising 45,000 channels of logged data. Test-type logging installations, primarily military, total 1300 logging installations with 150,000 channels.

Electronics components market in 1960 is predicted by L. Davis of GE as follows: Semiconductor sales $550 million ($400 million in 1959), including 130 million transistors valued at $315 million; Receiving tubes—435 million tubes, about same as 1959; Power tubes $300 million, 15% above 1959; TV picture tubes 13 million units, 5% above 1959.

American business firms employed 780,000 scientists and engineers (2/3 of nation's total) in January, 1959, says NSF, comprising 630,000 engineers and 150,000 scientists. About 35% were employed in R&D. Largest groups are in aircraft and parts, electrical equipment, chemicals, with more than 75,000 in each. Machinery and engineering and architectural services each employed from 50-75,000. Construction, fabricated metal products, primary metals, motor vehicles and equipment, each employed 30-50,000 men.

Federal R&D Budget for 1958, 1959 and 1960 (est.) is as follows (billions):

	1958	1959	1960
Total	$5.5	$7.2	$7.7
Dept. of Defense	4.4	5.6	5.8
AEC	0.64	0.77	0.83
NASA	0.08	0.30	0.43
Dept. of Health, Education, Welfare		0.24	
Dept. of Agriculture		0.12	
Dept. of Interior		0.062	
NSF		0.057	
Dept. of Commerce		0.028	
FAA		0.028	
Others		0.037	

TOTAL INDUSTRY SHIPMENTS
ELECTRICAL MANUFACTURING INDUSTRY

(All data in millions of dollars. Includes Exports and Interplant Transfers)

ELECTRICAL PRODUCTS	1958	1959 Preliminary	1960 Forecast
CONSUMER PRODUCTS	$ 5,406.1	$ 6,029.8	$ 6,301.1
LIGHTING EQUIPMENT	1,313.7	1,442.1	1,538.8
INDUSTRIAL ELECTRONICS AND COMMUNICATIONS EQUIPMENT	5,266.0	5,843.6	6,332.8
INDUSTRIAL EQUIPMENT	3,006.8	3,462.8	3,750.8
BUILDING EQUIPMENT	688.0	748.5	797.2
INSULATING MATERIALS	316.9	403.7	441.4
INSULATING WIRE AND CABLE	1,307.5	1,503.6	1,654.0
GENERATION, TRANSMISSION, AND DISTRIBUTION EQUIPMENT	2,047.0	2,079.4	2,242.3
TOTAL ELECTRICAL MANUFACTURING INDUSTRY	$19,352.0	$21,513.5	$23,058.4

Prepared by: NEMA Statistical Department, December 21, 1959.

$3 million NSF grant will provide Woods Hole Oceanographic Institution with new oceanographic vessel, completely instrumented.

ICS NEWS

New Prefixes For Units

WASHINGTON, D. C.—The National Bureau of Standards has decided to follow the recommendations of the International Committee on Weights and Measures to use new prefixes for denoting multiples and sub-multiples of units. The Committee adopted the prefixes at its meeting in Paris in the fall of 1958. In addition to the 8 numerical prefixes in common use, which are given in the table below, the Committee expanded the list by adding for four prefixes marked with an asterisk. Thus, for example, 10^{-12} farad is called 1 picofarad, and is abbreviated 1 pf.

Multiples and Sub-Multiples	Prefixes	Symbols
10^{12}	tera*	T
10^{9}	giga*	G
10^{6}	mega	M
10^{3}	kilo	k
10^{2}	hecto	h
10	deka	dk
10^{-1}	deci	d
10^{-2}	centi	c
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano*	n
10^{-12}	pico*	p

Pronunciation: tera = tĕr′a
giga = jī′ga
nano = nā′no
pico = pī′co

Temperature Control in Transistor Manufacture

PHILADELPHIA, PA.—To insure accuracy and reliability requirements of its all-transistor Type 7070 and 7090 electronic data processing systems, IBM manufactures a portion of the transistors.

Precise furnace temperature control is essential. Twenty electric furnaces, specially designed for the process of alloying dots and bonding base tabs onto the transistors, are equipped with automatic controls. Furnace temperatures, which vary from 300 to 800°C during the various phases of the process, are controlled by duration-adjusting-type (DAT), 2-action Speedomax H controllers with thermocouple sensing elements. Portable precision potentiometers, or adjustable-range, adjustable-zero Speedomax G recorders with a traveling thermocouple are used for spot checks. Temperature gradients are held within 2°C. Information can be obtained from Leeds & Northrup Co.

CIRCLE 160 ON READER-SERVICE CARD

Electrical Manufacturers Hold Convention

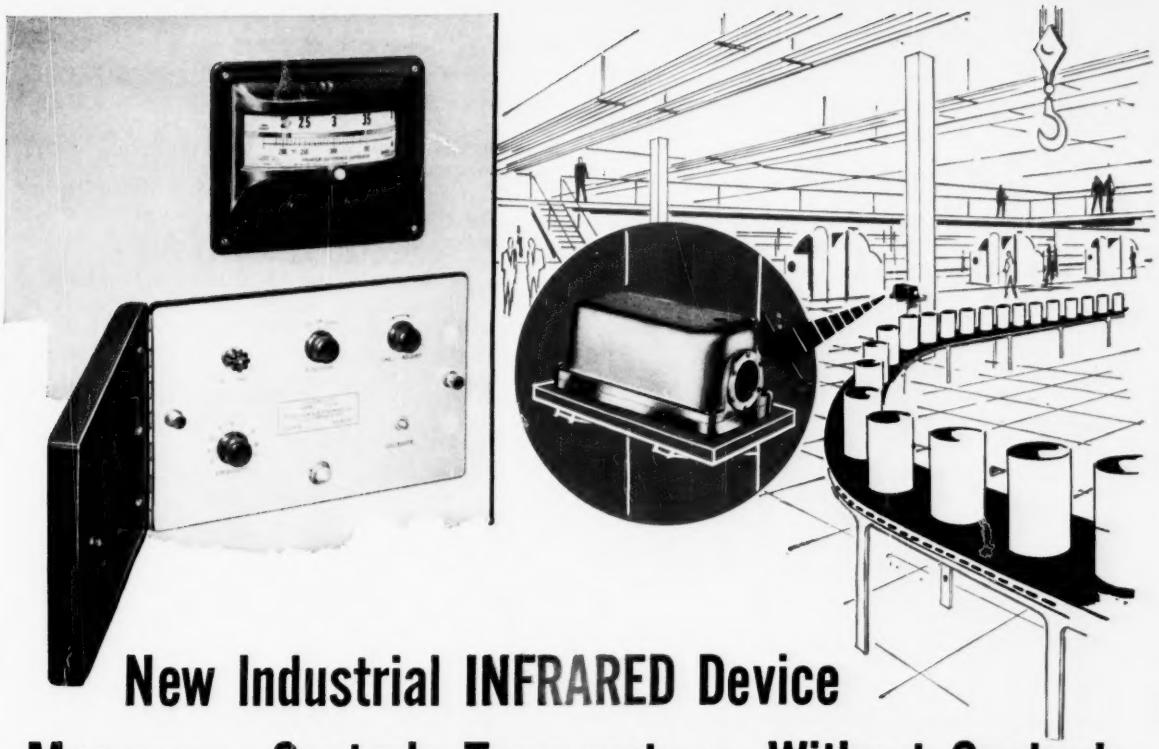
ATLANTIC CITY, N. J.—NEMA, the National Electrical Manufacturers Association, held its 33rd Annual Convention here early in November and elected *N. J. MacDonald,* president of Thomas & Betts Co., as its new *president.*

Election were also held in NEMA's subdivisions. Pictures show officers of two sections: The three-men group represents the *Electrical Indicating Instrument Section* and is l. to r.: vice chairman *W. R. Triplett,* The Triplett Electrical Instrument Co.; past chairman *W. H. Steinkamp,* Daystrom Inc.-Weston Instruments Div.; and chairman *J. R. Whiteside,* Simpson Electric Co. The five men in the other picture are the officers of the *Precision Snap-Acting Switch Group, Industrial Control Section.* Seated l. to r. are: *J. F. Page,* American Radiator & Standard Sanitary Corp.; *E. F. Kurtz,* Texas Instruments, Inc.; *R. W. Pashby,* Minneapolis-Honeywell Regulator Co. Standing l. to r. are: *Louis Putze,* Controls Co. of America; *Daniel Schwarzkopf,* The W. L. Maxson Corp.

Bailey Forms Heat Cycle Analysis Institute

CLEVELAND, OHIO.—The first 2-week workshop session of Bailey Meter Co.'s newly formed Institute of Practical Heat Cycle Analysis was held October 5 through 16, 1959. The workshop session covered subjects such as high-accuracy measurement and testing, turbine and heater characteristics, and the "gain" approach to cycle analysis. Visiting engineers made calculations and studied methods of setting up computer programs for heat rate problems, analyzed different cycles, and determined cycle malfunctions from data intentionally provided for this purpose.

Four similar workshop sessions are scheduled for 1960.



New Industrial INFRARED Device Measures...Controls Temperature...Without Contact

Since World War II, there has been an accelerated development of materials and components for infrared guidance and reconnaissance systems. A number of components and techniques, developed for military use, are now being applied to industrial instrumentation. Radiation Electronics Company has developed several types of infrared instruments for remote temperature measurement and control now being used in the production and testing of paper, glass, rubber, metals, and plastics.

The Thermodot radiation thermometer, Model TD-3, has been designed specifically for production plant operation. Since the operation is completely remote, Thermodot readily measures and controls the temperature of moving and inaccessible surfaces. The high sensitivity of Thermodot provides reliable measurements at low temperatures—the lowest standard range is 400°F full scale. Other standard ranges extend to 6000°F. Measurements are completely automatic and continuous, and the response time is 0.3 seconds. An internal calibration source provides rapid and accurate standardization.

Thermodot measures the temperature of a remote object without physical contact. Operation is based on the fact that an object emits thermal radiation as a function of its temperature. An infrared lense, located in the Thermodot optical head, is used to focus this radiation onto a sensitive infrared detector. The detector generates a signal voltage accurately proportional to the radiation intensity, and the signal is amplified to drive an indicator calibrated directly in temperature.

The infrared radiation detecting element is hermetically sealed to prevent contamination by vapors and fumes. In addition, the optical assembly is housed in a sturdy, dust-tight enclosure and is insensitive to vibration and shock as normally encountered in the plant. Ambient temperature variations from 20-120°F have no effect on its operation.

Complete Thermodot Model TD-3 Consists of Optical Head, Power Supply and an Indicating Controller

SPECIFICATIONS OF THERMODOT MODEL TD-3

WORKING DISTANCE . . Any range greater than one foot (prefocused at factory).

SPEED . . . . . Responds in 0.3 seconds.

CALIBRATION . . Internal reference source permits accurate standardization in seconds.

EMISSIVITY COMPENSATION . . Adjustable at control panel.

AMBIENT CONDITIONS . Unaffected by ambient temperature variations from 20-120°F.

For more information, write for Bulletin R-100, or visit our Booth No. 109 at the ISA Exhibit February 2-11 in Houston.

RADIATION ELECTRONICS CO.
5600 Jarvis Avenue, Chicago 48, Illinois · Telephone: SPring 5-2400

DIVISION OF COMPTOMETER CORPORATION

CIRCLE 18 ON READER-SERVICE CARD

EPLAB

PYRHELIOMETER
For the Measurement of
SOLAR RADIATION

Eppley Pyrheliometers are used for solar radiation measurements at ninety-eight weather stations in the continental United States, Canada, Alaska, Greenland, Iceland, Caribbean Sea, and the Pacific Ocean. Sixty-two of these stations are under the direction of the United States Weather Bureau.

The Eppley Pyrheliometer was adopted as standard equipment by the Weather Bureau after considerable experimentation. It was found to be the best instrument so far tested by the Bureau.

Used in conjunction with a suitable recorder, the Eppley Pyrheliometer will provide an accurate and reliable record of total solar and sky radiation on a horizontal surface.

Bulletin No. 2 on Request

THE EPPLEY LABORATORY, INC.

Scientific Instruments

2 Sheffield Ave.
Newport, Rhode Island U. S. A.

CIRCLE 19 ON READER-SERVICE CARD

Instrumentation at U. S. Steel

CLEVELAND, OHIO.—Two novel applications in U.S. Steel show progress being made.

Fairless Works at Fairless Hills, Pa., are putting in a new "Metrotype" digital data system to monitor and log temperatures on sixteen soaking pit recuperators. The system uses solid-state circuitry; was chosen by the considerations of saving panel space and reducing the time required for routine operations such as changing charts, inking pens, etc. Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland 10, Ohio manufactures the "Metrotype" system.

Cuyahoga Works at Cleveland will apply a new infrared device for measuring the speed of hot steel rod in its rolling operation. The device, designed and built by Lindly and Company, Inc., 248 Herricks Rd., Mineola, N. Y., (see picture) consists of two units, a detecting head

and the associated electronic section. It measures the length of time it takes the leading and trailing ends of a length of heated steel to pass two points a known distance apart, whereby the speed of the steel at various stages of rolling can be computed.

FOR BAILEY CIRCLE 159 ON READER-SERVICE CARD
FOR LINDLY CIRCLE 161 ON READER-SERVICE CARD

STROMBERG-CARLSON's *Robert L. Demig*, head of Nuclear Systems Engineering, and *Donald D. Welt*, Nuclear Applications Engineer, recently conducted a seminar for the Instrumentation and Controls Division of the Oak Ridge National Laboratory. The subject was transistorized instrumentation and controls for nuclear reactors.

SERVO CORP. OF AMERICA during the sessions of the National Electronics Conference in Chicago, held a symposium on the latest methods, techniques, trends, and laboratory equipment being used to teach servomechanisms and automatic controls in engineering schools and industrial training programs, to which one hundred educators and training directors of the Illinois-Indiana area were invited.

PERKIN-ELMER's West German Subsidiary has received a $30 million contract to produce Sidewinder infrared guided air-to-air missiles for NATO nations.

the highest, the coldest, the hottest ... IN THE SMALLEST *SPACE!*

Tenney-mite STRAT environmental chamber

Altitudes to 200,000 ft., temperatures from −100° F to +350° F, in only 4 square feet of floor space. Now, any company can own a combined altitude and temperature test chamber . . . without sacrificing much valuable floor space. And the investment, too, is reasonable.

Only Tenney Engineering, world's largest and most experienced creator of environmental equipment, could produce the Tenney-mite Strat. Write for further information.

Write for a descriptive catalog and complete information on Tenney's research and development, engineering consultation, and design services.

Tenney ENGINEERING, INC.

OLDEST AND LARGEST MANUFACTURER OF ENVIRONMENTAL EQUIPMENT

1090 SPRINGFIELD ROAD, UNION, NEW JERSEY • PLANTS: UNION, NEW JERSEY AND BALTIMORE, MARYLAND

CIRCLE 20 ON READER-SERVICE CARD

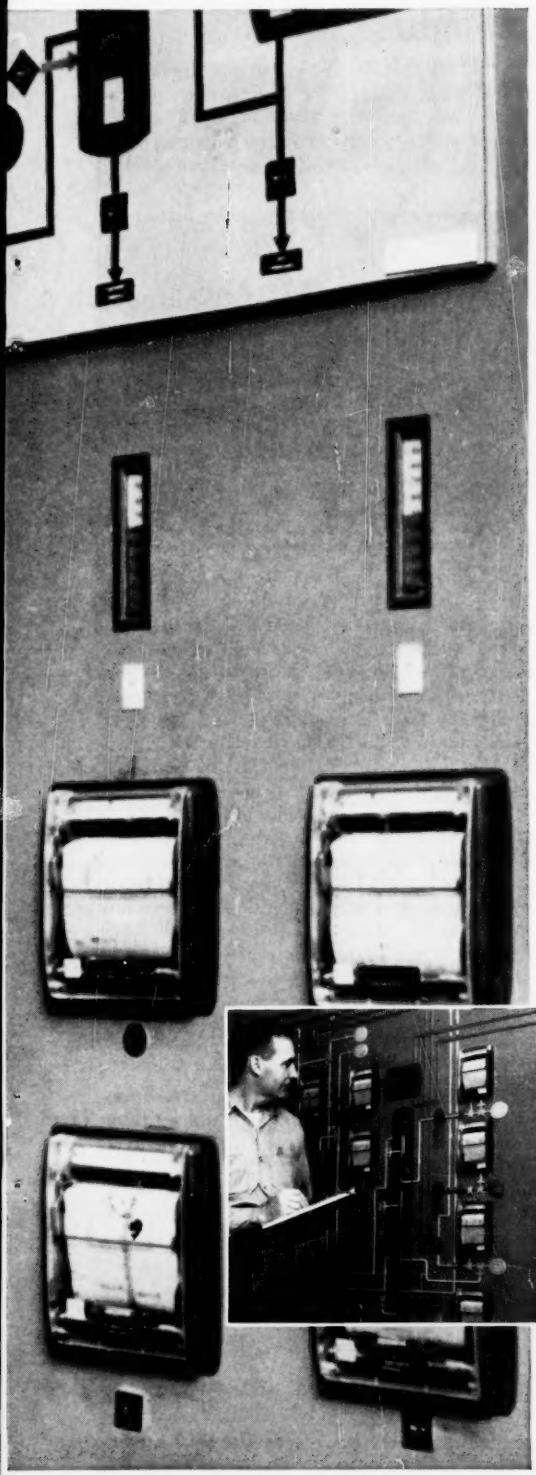
Esso looks to

Consotrol Control panel for Powerformer* at Esso's Bayway Refinery, Linden, New Jersey. Complete Consotrol Control Station slides out from front of panel as a unit — makes servicing easier for Esso technicians.

*Trade mark, Esso Standard Oil Company

CIRCLE 21 ON READER-SERVICE CARD

Consotrol* instruments



for dependable control at their Bayway Refinery

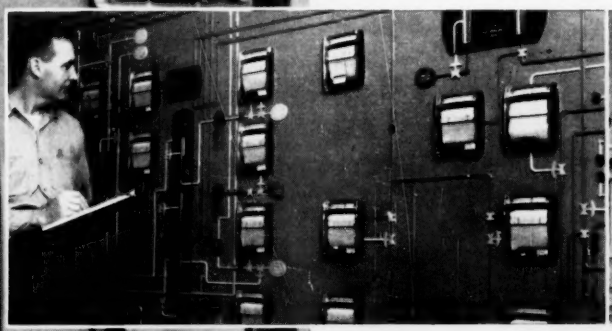
Precise, dependable, centralized control . . . full-scale, easy-to-read chart records . . . simplified maintenance from the front of the panel. No wonder leading refineries like Esso specify Foxboro pneumatic Consotrol instrumentation.

Consotrol control stations are so compact, four can fit where one circular chart instrument used to go. Yet recorders still have a full-scale, 4-inch chart — can furnish continuous recording of up to 3 different variables on the same chart.

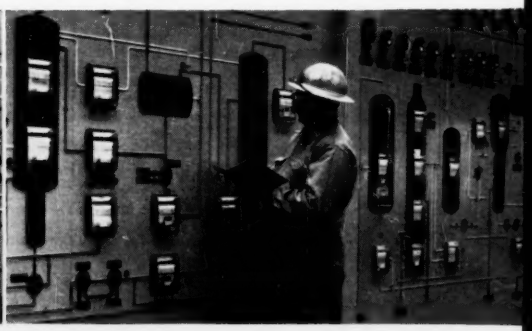
Consotrol M 58 Controllers handle a full-range of control functions: auto-selector . . . cascade and ratio systems . . . automatic batch control.

Get the complete story on pneumatic Consotrol instrumentation by writing for Bulletin 13-18. **The Foxboro Company, 461 Neponset Ave., Foxboro, Mass.**

*Reg. U.S. Pat. Off.



▲ Foxboro control panel for #6 Pipe Still was installed in 1952. Consotrol recorders have a full-scale 4" chart which travels vertically. Pen arm moves in an arc — eliminates extra linkage common to instruments that must convert rotary motion to straight-line pen travel.

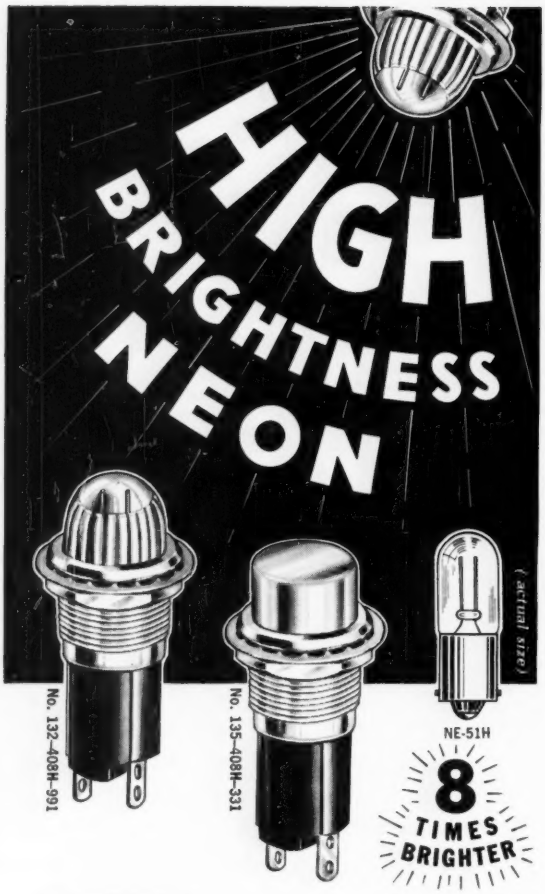


▲ This hydrofiner full-graphic panel includes 54 Consotrol Recorders, 44 Controllers. Ethylene Plant control panel (not shown) includes another 100 Foxboro Pneumatic Consotrol instruments.

CIRCLE 21 ON READER-SERVICE CARD

FOXBORO

REG. U.S. PAT. OFF



DIALCO® PILOT LIGHTS

with Built-in Resistor
(a patented DIALCO feature)
for the Neon Glow Lamp NE-51H (High Brightness)

RUGGED: The NE-51H Neon Glow Lamp is made to resist vibration and is proof against sudden failure. It may be operated at about 3 times the level of current applied to the standard neon lamp, and it will produce 8 times as much light—*with long life!* Requires low power—less than 1 watt on 250 V circuit. Recommended for AC service (may be used on DC circuits above 160 V).

BUILT-IN current-limiting resistor (U.S. Patent No. 2,421,321): For use on 105-125 volt and 210-250 volt circuits. In DIALCO Pilot Lights, the built-in resistor is completely insulated in moulded phenolic and sealed in metal.

COMPACT: Units are available for mounting in 9/16" and 11/16" clearance holes... in a wide choice of lens styles and colors, terminal types, metal finishes, etc. Meet applicable MIL Spec and UL and CSA requirements.

Every assembly is available complete with lamp.

SAMPLES ON REQUEST—AT ONCE—NO CHARGE

Ask for Bulletin No. 100 and Catalogue L-161B.

Foremost Manufacturer of Pilot Lights
DIALIGHT CORPORATION

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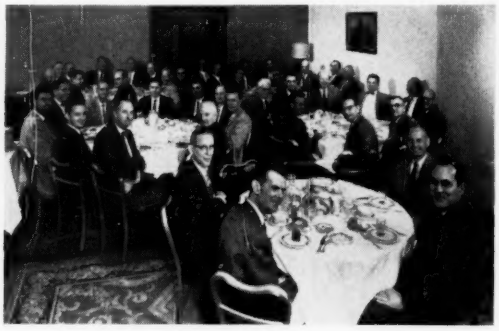
CIRCLE 22 ON READER-SERVICE CARD

NEWS —CONTINUED

Shell Oil Holds Annual Measurement And Control Committee Meeting

CHICAGO, ILL.—For more than fourteen years Shell Oil Company has gathered together a committee of competent engineers concerned with instrumentation to discuss measurement and automatic control problems. This meeting is now held annually, and for eleven consecutive



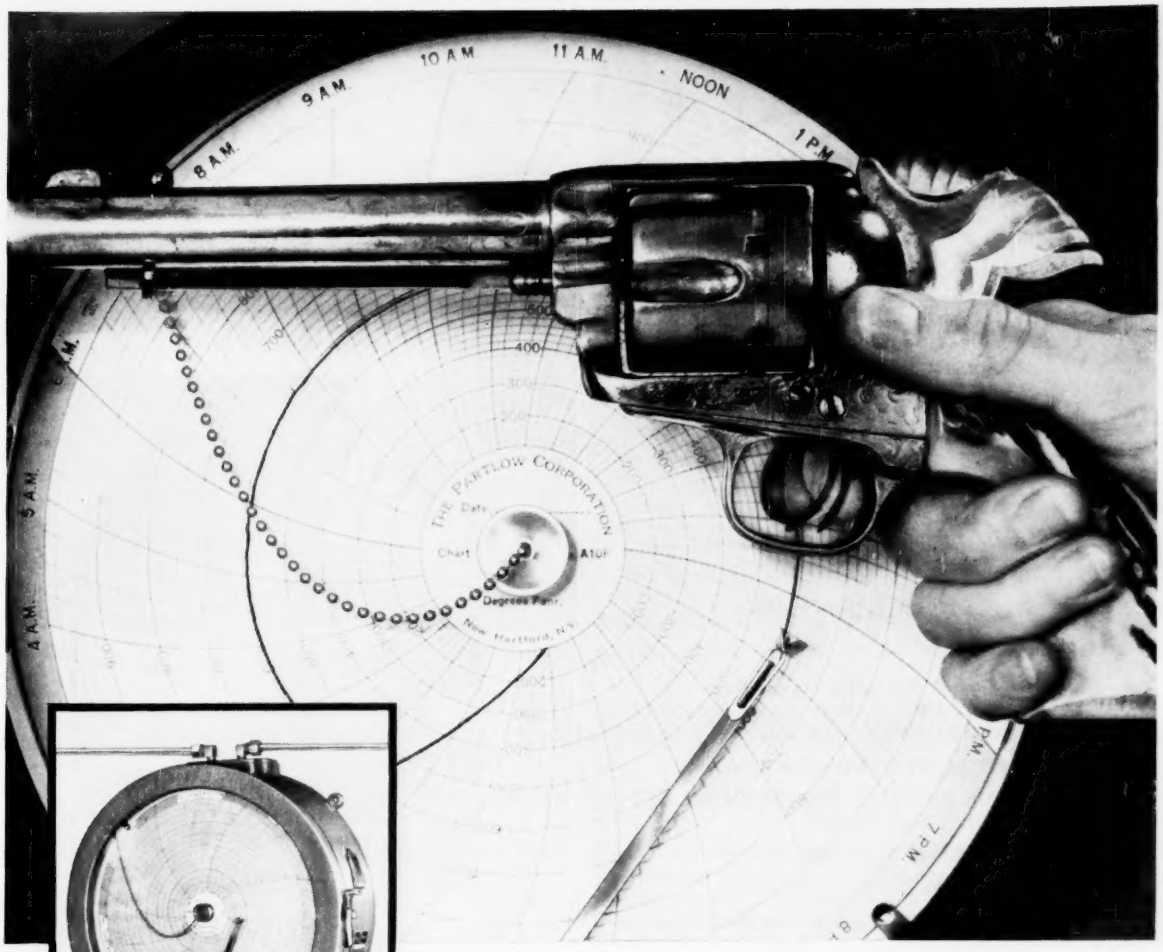
years has been held in conjunction with the annual ISA instrument show. This year 35 domestic experts and 8 foreign visitors attended the sessions of the Measurement and Control Committee in Chicago. They came from four major departments of Shell Oil Company along with affiliated Shell companies including Shell Development Company, Shell Pipe Line Corporation, Shell Oil Company of Canada, Ltd., and Shell Chemical Company, Foreign visitors represented B.I.P.M. and C.I.P.M. from the Hague, Holland, Royal Dutch Shell Laboratories, Amsterdam and Compania Shell de Venezuela.

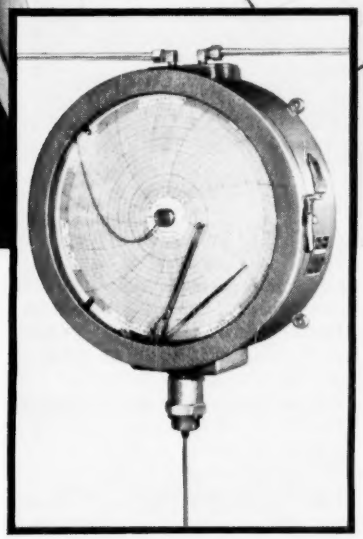
The usual procedure at these meetings is first to examine all company operations with simplifications, improvements, and economic aspects in mind; and then to examine every piece of new measuring and controlling equipment spotted at the show, and to discuss its application possibilities in the various processes of the company. Thus members who have not seen one or the other device can go back to the show and supplement their knowledge.

FISHER GOVERNOR CO. has introduced a new mobile display truck equipped with sectional and working models of regulators and controllers, and an educational movie "Muscles of Control."

◀ FISHER GOVERNOR NEW MOBILE DISPLAY

EAI (Electronic Associates, Inc.) recently held a seminar on structural analysis through analog computation at its Princeton Computation Center, attended by 60 engineers and mathematicians.





The Control Geared for

HAIR TRIGGER RESPONSE

even to Fractional Changes in Temperature!

NEW *Recording Pneumatic Temperature Control, Model RVA, available in any of 10 ranges from -30° to 1100° F.*

Extreme sensitivity—reflected in lightning-fast reaction to temperature changes—is a characteristic of *all* Partlow controls. Partlow Recording controls, however, *prove it in writing* . . . You can see for yourself how exceptional bulb sensitivity, teamed with advanced mechanical design, provide a minimum of "saw-toothing" on start-up, and maintain a rigid line of control when temperature reaches a predetermined set point.

Instant response, of course, is just one of Partlow's many built-in advantages. Another is rugged *design simplicity* that does away with hair springs and delicate electronic gadgets . . . that requires no electronic amplification . . . that permits fast, "screwdriver" replacement of the thermal element *right out in the field.*

If you use or manufacture process equipment within the -30° to 1100° F. range, there's a Partlow Pneumatic, electric or self contained gas control to fit your application *precisely*. Recording, indicating and non-indicating models available. For full details write The Partlow Corp., New Hartford, New York, Dept. IA-160. Export: Ad. Auriema, Inc., 85 Broad St., New York 4, N. Y.

You can pay more but you can't buy better than

PARTLOW

TEMPERATURE CONTROLS

CIRCLE 23 ON READER-SERVICE CARD

CARL ZEISS

Made in West Germany

Symbol of High Quality

SINCE 1846

A few of the many outstanding instruments which embody the traditions of this famous trade-mark:

UNIVERSAL MEASURING MICROSCOPE

LARGE and SMALL TOOLMAKER'S MICROSCOPES

INTERFERENCE MICROSCOPE

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EPI-TECHNOSCOPE

GAUGE BLOCK INTERFEROMETER

CIRCULAR DIVISION TESTER

CAM SHAFT TESTER

VERTICAL and HORIZONTAL METROSCOPES

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ULTRAPHOT II for incident illumination with automatic exposure-setting device

PHOTO MICROSCOPE for incident illumination with automatic exposure-setting device

SALES AGENTS WANTED

Write for free, detailed specifications on equipment of interest to you.

CARL ZEISS, INC.

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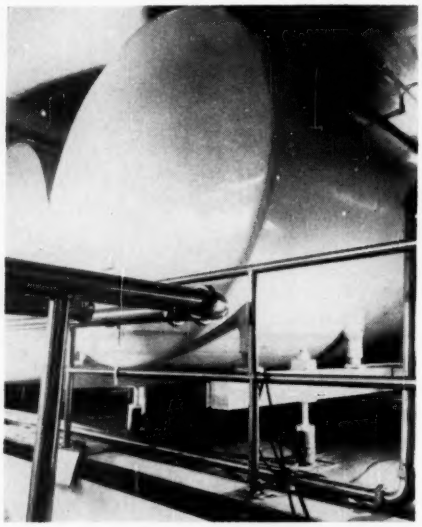
COMPLETE SERVICE FACILITIES

Oberkochen, West Germany

CIRCLE 24 ON READER-SERVICE CARD

Dairy Converts to Load-Cell Weighing System

WALTHAM, MASS.—Installation of a load-cell weighing system at Thompson's Honor Dairy, Inc., Washington, D. C., has not only solved the problem of periodically supervising the bulk tank gages at the various farm suppliers, but has resulted in highly efficient handling of the milk and savings to the company.



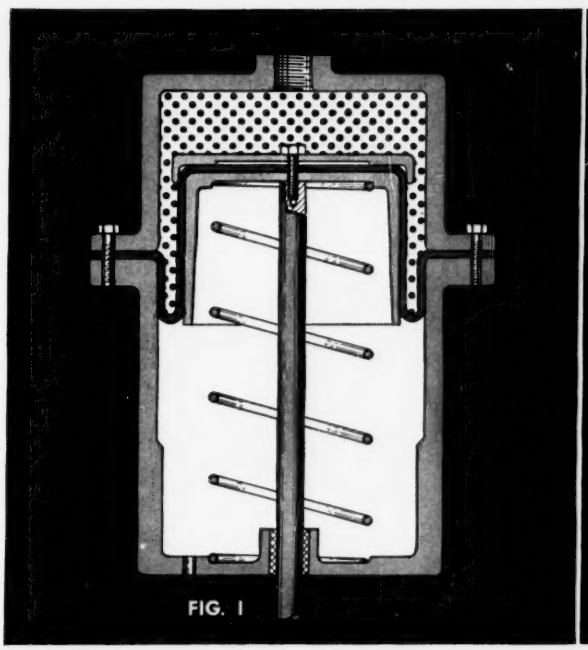
Previous to converting to bulk milk pickup the dairy employed the conventional method of weighing milk dumped from the cars into a weigh tank on mechanical scales. After the conversion, all milk shipments were accepted on a volumetric basis. Inherent in this system were inaccuracies of measuring foam as milk, or the errors of the gages when bulk tank settled or went out of level, besides human errors in reading dipsticks and volume gages. Discrepancies amounted to as much as 3½%.

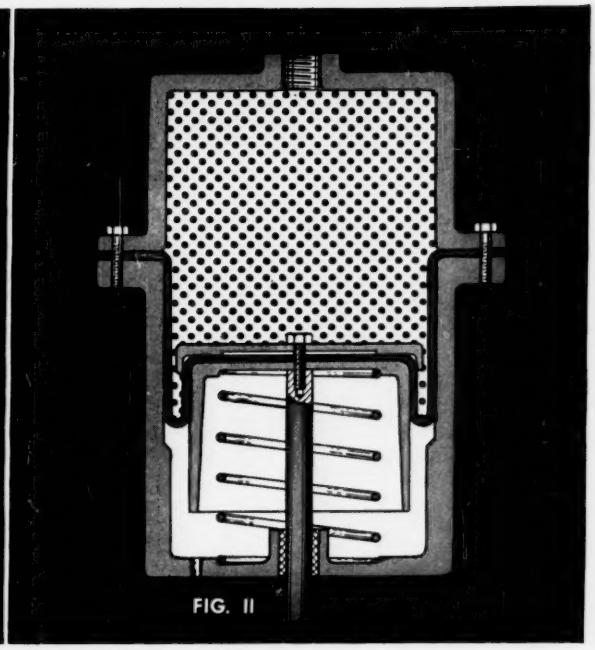
Requirements of the supervising authorities stipulate an accuracy of weighing systems within 0.05%, and this accuracy was easily met by Type CXX SR-4 load cells which have been installed beneath each end of two beams which support the storage tank after a structural conversion. Details can be obtained from Baldwin-Lima-Hamilton Corp., Electronics and Instrumentation Div., 42 Fourth St., Waltham 54, Mass.

CIRCLE 162 ON READER-SERVICE CARD

EBEX TECHNICAL INSTITUTE in Orem, Utah is giving a 10-chapter correspondence course on Analog Computers (Course 62-I) for a tuition fee of $45.00 per unit, including grading (optional) and credit toward certificate of completion.

GENERAL ELECTRIC has received a $2¼-million order for a complete electrical system to be installed by a major eastern steel producer in a new 11″ three-strand merchant mill.





For Actuators . . . Seals . . . Instruments

Nothing rolls like a Bellofram®

Rolling Diaphragm. It's frictionless!

The Bellofram Rolling Diaphragm provides ultra-sensitive response in hydraulic or pneumatic devices where frictionless, long-stroke action in small diameter configurations is required . . . and where flex life of millions of cycles is necessary.

These desiderata are achieved through the *rolling* action of a flexible, thin-sidewall diaphragm consisting of a high-tenacity fabric overlay embedded in elastomeric material.

Fig. I shows how Bellofram Rolling Diaphragm conforms to the piston. Fig. II shows how, as the piston descends under pressure, the Bellofram Rolling Diaphragm *rolls* off the piston's sidewall and onto the cylinder's sidewall in a smooth, continuous, frictionless movement.

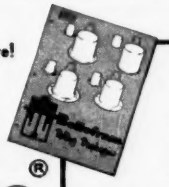
The Bellofram principle can be applied widely in actuators, pumps, instruments, seals, accumulators, and fluid dampers.

Which of these advantages are you looking for?

To the designer confronted with situations for which conventional bellows, O-rings, or cup packings are inadequate, Bellofram Rolling Diaphragm offers a constellation of advantages found in no other product:

1. **Friction-free (low hysteresis).**
2. **No break-out friction effects.**
3. **Non-porous and leakproof.**
4. **Constant area in all piston positions.**
5. **Almost infinite flex life (millions of cycles).**
6. **Sensitivity to extremely small pressure changes.**
7. **No mechanical spring gradient.**
8. **Compatibility with practically all environmental gases or fluids.**
9. **Automatic de-icing action.**
10. **Free positioning with complete relaxation at any point in the stroke.**
11. **Does not require close machine finish tolerances on pistons and cylinders.**
12. **Freedom from abrasive wear.**
13. **One hundred stock sizes. Four mounting configurations. Special types and sizes designed to order.**
14. **Excellent temperature stability from —85°F. to 550°F. (from —120°F. to 700°F. in some cases). Wide range of working pressures: 1 inch H_2O to 500 psi (up to 1200 psi in some cases). Effective pressure areas from .028 to 108 square inches. Cylinder bore diameters from .25 to 12 inches. Extended range of stroke (.01 to 12 inches).**

Send for **FREE BROCHURE** that tells you more!



Bellofram Rolling Diaphragms are protected by U.S.A. and foreign patents.

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Bellofram Corporation, 5 Blanchard Rd., Burlington, Mass.

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From Honeywell

A compact inexpensive controller

- **Automatic temperature control**
- **Automatic pressure control**
- **Automatic control of liquid level**
- **Automatic humidity control**

Exclusive Honeywell Versa-Tran replaces old fashioned mechanical control *at low cost.*

Now—a transistorized controller that's versatile enough to be used in many applications. Small, compact, with complete repeatability. No tubes, no warm up time, gives instant reaction. Works with sensors that can be thermistors, probes, resistance bulbs, pressure transducers or humidity elements. Can be used in such varied applications as packaging machines, injection molding machines, cooking vats, tire recapping, ice cube makers, and tanks, etc. Has a temperature control range from minus 60 degrees to plus 1400 degrees F.

The Versa-Tran is the result of traditionally superior Honeywell engineering. For information, call your nearest Honeywell office and our industrial control sales engineer will call. Or write: Minneapolis-Honeywell, Department IC-1-24, Minneapolis 8, Minnesota. In Canada, write: Honeywell Controls Ltd., Vanderhoof Avenue, Leaside, Toronto 17.

Honeywell

75th YEAR — PIONEERING THE FUTURE

H HONEYWELL *First in Control*

CIRCLE 25 ON READER-SERVICE CARD

ICS EVENTS

February 18-19

Twin City Section of I.S.A. 5th Annual North Central Area Automation Symposium, Lowry Hotel, St. Paul, Minn. For information write R. E. Hopper, International Div., Minneapolis-Honeywell, 2753 Fourth Ave., S., Minneapolis 8, Minn.

February 25-26

Seventh Scintillation Counter Symposium, Hotel Shoreham, Washington, D. C. For information write G. A. Morton, RCA Laboratories, Princeton, N. J.

March 16-18

Twenty-Third Annual Short Course for Superintendents and Operators of Water and Sewage Systems, will be held on campus of Louisiana State University. For information write Fred H. Fenn, College of Engineering, Louisiana State University, University Station, Baton Rouge 3, Louisiana

March 21-24

IRE National Convention, Coliseum and Waldorf-Astoria Hotel, New York, N. Y. Write E. K. Gannett, Institute of Radio Engineers, 1 East 79th St., New York 21, N. Y.

April 6-8

Institute of Environmental Sciences National Meeting, Biltmore Hotel, Los Angeles. For information write Bruno Forscher, 16446 Bircher St., Granada Hills, Calif.

April 20-22

Texas A & M Symposium on Instrumentation for the Process Industries, will be held on campus of Texas A & M. For information write N. E. Welch, Chemical Engineering Dept., Agricultural and Mechanical College of Texas, College Station, Texas

April 27-29

Sixth Annual Southern ISA Conference & Exhibit and First Pulp and Paper Division Symposium, Pensacola, Florida. For information write W. H. Matthews, P. O. Box 4426, Pensacola, Fla.

May 3-5

1960 Western Joint Computer Conference, Jack Tar Hotel, San Francisco, Calif. For information write H. M. Zeidler, Stanford Research Institute, Menlo Park, Calif.

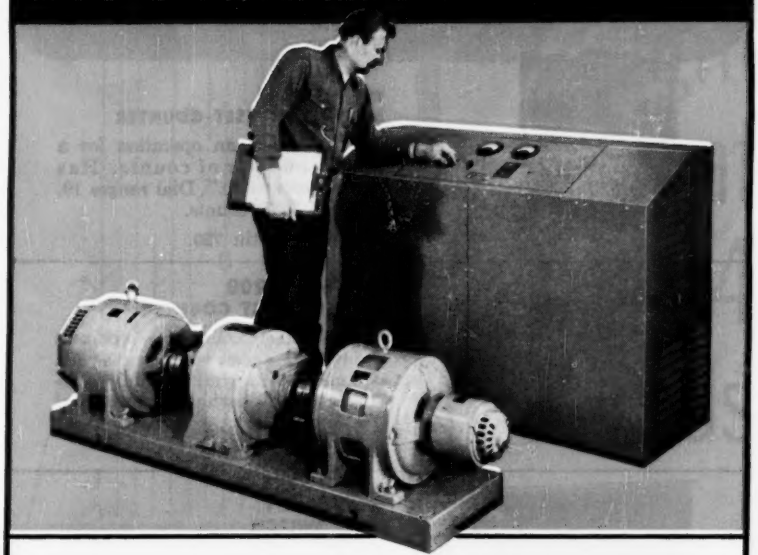
May 9-11

Annual PGMTT Symposium, sponsored by IRE Professional Group on Microwave Theory and Techniques, Hotel del Coronado, Coronado, Calif. For information write David B. Medved, CONVAIR, Division of General Dynamics, Mail Zone 6-172, Box 1950, San Diego 12, Calif.

June 16-18

Fifth Annual Symposium and Exhibit of American Scientific Glassblowers Society, Penn-Sheraton Hotel, Pittsburgh, Penna. For information write W. E. Barr, Gulf Research & Development Company, P. O. Box 2038, Pittsburgh 30, Penna.

SAVE 50% to 90% ON DC POWER SYSTEMS



The modern way to boost electronic power-system reliability is also the best way to cut cost, size, heat-loss, and complexity... by interposing a precisely-regulated motor-alternator set as a buffer-regulator between your DC power supplies and the power line. Typical Savings: 50-90%.

This technique often eliminates the need for regulated supplies... simple brute-force rectifiers suffice. If regulation **is** still necessary, the stress on the regulator is greatly reduced, hence remarkable savings in cost, etc.

Everybody's doing it... in Computers, Automation, Telemetry, Ground Support. Incidentally, **ignore** old-fashioned prejudices about rotary equipment... this is "turn-it-on-and-forget-it" gear... we even build them **brushless,** if you object to routine once-a-year maintenance.

Skeptical? Write today for this complete, authoritative, 32-page illustrated technical manual describing ESCO-RI PRECISE POWER SYSTEMS.

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Partners in Power

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Fireside 8-6203

RI REGULATORS, INC.

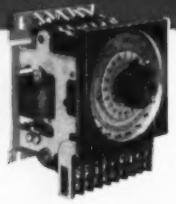
CIRCLE 26 ON READER-SERVICE CARD

Count Control

COMPONENTS

FOR AUTOMATING INDUSTRIAL PROCESSES

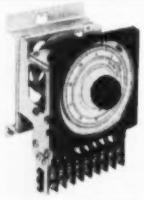
featuring adjustable count · automatic reset · 10 ampere switches



model HZ4
MICROFLEX RESET COUNTER

Use to control an operation for a preset number of counts. Has spring reset to "0." Dial ranges 19, 400 and 1,000 counts.

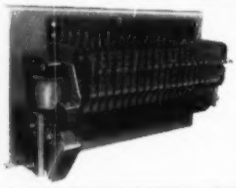
Ask for bulletin 720.



model HZ200
ADD-SUBTRACT COUNTER

Add-Subtract counter — operates from ADD pulses which trip switch at maximum limit — and SUBTRACT pulses which trip switch at "0" limit.

Ask for bulletin 740.



model MT
STEP SWITCH

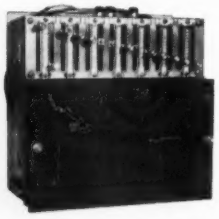
Use for sequence control from pulses — 19 contacts — 60 cycle coil-break out cam lugs.

Ask for bulletin 780.

model HZ6
MICROFLEX REVOLUTION COUNTER

Use to control an operation as a function of mechanical movement — drive shaft can be mechanically connected to machine, spindle, conveyor, etc.

Ask for bulletin 730.



model HM
MULTIFLEX *(Multiple Circuit)* TIMER

Use for sequence control of 1 to 7 circuits. With shaft drive for mechanical connection to an external drive mechanism.

Ask for bulletin 130.

Write us regarding your count problem. Services of Sales Engineers in 25 district offices are available without obligation. Address Dept. IC-160.

EAGLE SIGNAL COMPANY
A DIVISION OF THE GAMEWELL COMPANY
MOLINE, ILLINOIS

MANUFACTURERS OF THE MOST COMPLETE LINE OF INDUSTRIAL TIME-COUNT CONTROLS

CIRCLE 27 ON READER-SERVICE CARD

BOOKS

Dynamische Vorgange in linearen Systemen der Nachrichten- und Regelungstechnik (Dynamic Actions in Linear Systems of Communications and Automatic Control) by Dr. Hans Kaufmann, [c 1959] R. Oldenbourg, 145 Rosenheimer Str., Munich, West Germany, 211 p., 9¼", clothbound $7.00. Author puts emphasis on giving simultaneous considerations to time and spectral response of communication systems when using the mathematical representation by Laplace transforms.

CIRCLE 163 ON READER-SERVICE CARD

Analog Methods, by Walter J. Karplus and Walter W. Soroka, second edition [c1954] McGraw-Hill Book Co., Inc., 330 West 42nd St., New York 36, N.Y., 483 p., 9", clothbound, $12.50. A comprehensive survey of all analog methods and techniques in use today. Second, thoroughly revised edition shifts emphasis from mechanical to electrical and electronic equipment.

CIRCLE 164 ON READER-SERVICE CARD

Modern Electronic Components, by G.W.A. Dummer [c1959] Philosophical Library, Inc., 15 E. 40th St., New York 16, N. Y., 472 p., 8½", clothbound $15.00. Book presents a comprehensive survey of characteristics of the more common components including behavior under various environmental conditions. Extensive bibliography refers to specialized information.

CIRCLE 165 ON READER-SERVICE CARD

Physical Methods of Organic Chemistry, edited by Arnold Weissberger, third completely revised edition, Part I, ([c1959] Interscience Publishers, Inc., 250 Fifth Ave., New York 1, N. Y., 918 p, 9", clothbound, $24.50. Vol. 1, Part 1 in the Technique of Organic Chemistry Series, this third edition has been expanded to four parts, augmented by 1000 pages, and contains 16 new chapters.

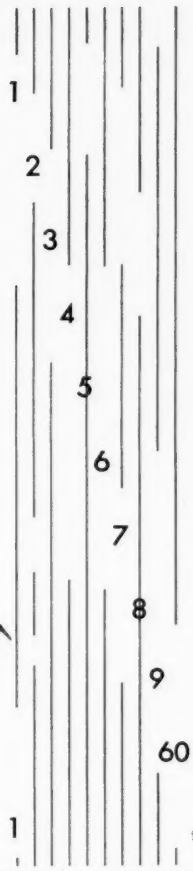
CIRCLE 166 ON READER-SERVICE CARD

Symposium on Particle Size Measurement, presented at the Sixty-first Annual Meeting, Boston, Mass., June 26 and 27, 1958, [c1959] American Society for Testing Materials, 1916 Race St., Philadelphia 3, Pa., ASTM Special Technical Publication 234, 310 p., 9", clothbound $6.25; to members $5.00. Contains 14 papers of the symposium and two additional papers previously published by ASTM.

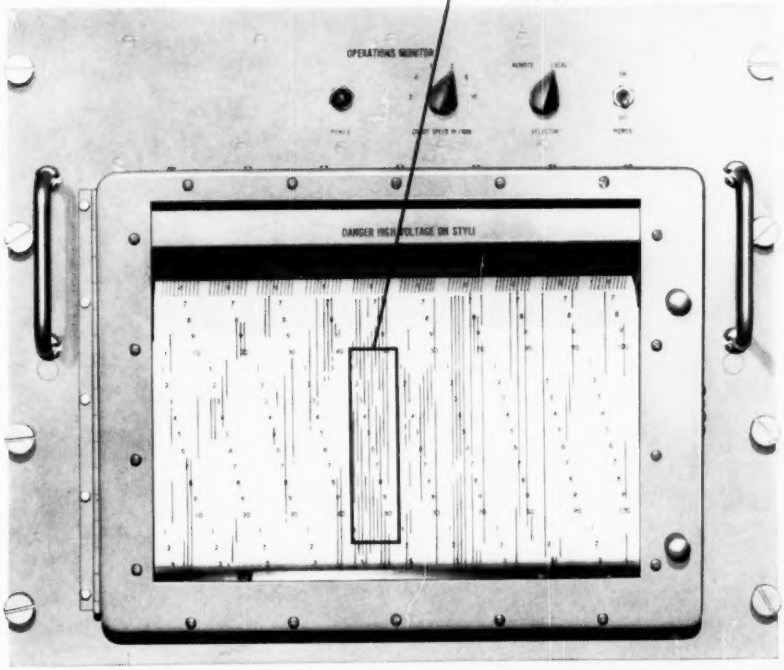
CIRCLE 158 ON READER-SERVICE CARD

Continued on page 114

CIRCLE 28 ON READER-SERVICE CARD →



insight at 4 milliseconds



recorded with Brush operations monitors. Multiple high-speed events are reported in writing within 4 milliseconds of occurrence—to establish the basis for split-second, million dollar decisions necessary in today's complex control systems. Up to 120 separate "on-off" event signals are monitored and permanently recorded on a chart only 12" wide. Fixed-stylus electric writing provides sharp, reproducible traces of uniform clarity. Chart speeds from one to 250 mm/sec permit a precise interpretation of all events, with resolution up to 500 signal changes per second. For military or industrial analysis and control, no direct writing recording system can match the capabilities of Brush Operations Monitors. Write today for complete specifications and application data.

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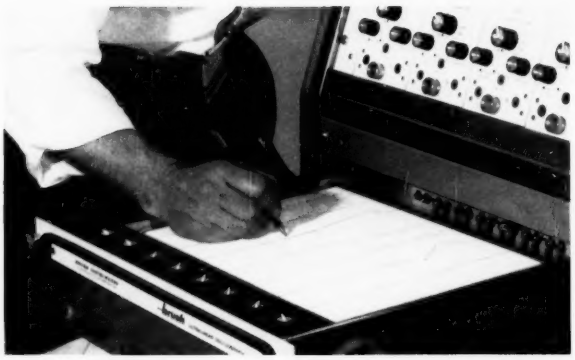

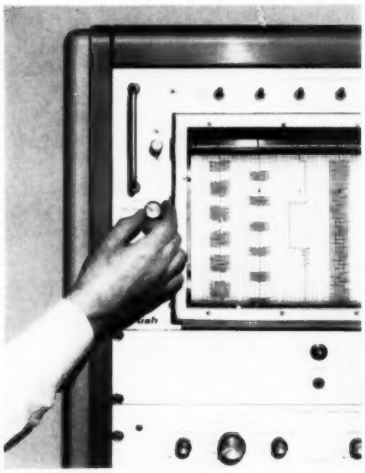

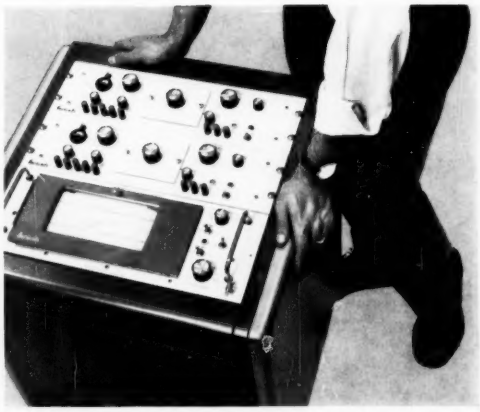

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ICS **BRIEFS**

Probability Distribution Analyzer

In the subsequent description the PDA is being considered as operating with the GPS Analog Computer, in the simulation study of randomly disturbed control systems . . . From each member of the ensemble the probability generator determines at one or more preset points along the time axis whether the amplitude of $y(t)$ is equal to or greater than an arbitrarily chosen voltage level V_o. If the amplitude is greater than V_o it is termed a success—otherwise a failure. A probability of success may be defined by the ratio of the counted number of successes to the total number of trials or samples. The probability thus defined if measured as a function of V_o is by definition of the probability distribution of $y(t)$. That is, the PDA can determine the function

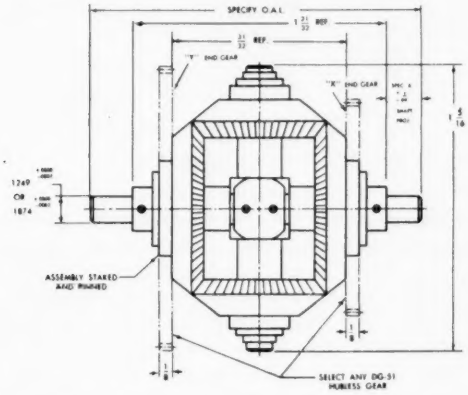
$$P_r(y \geq V_0) \cong \int_{V_0}^{+\infty} f(y)dy$$

From the probability distribution, it is possible to determine, for example, the RMS of the variable y whether the RMS is a function of time or not, since $Pr\ (y \geq V_o)$ can be determined as a function of time if it is not time invariant.—(*From new 4-page Bulletin PDA-675F, GPS Instrument Co., Inc., 180 Needham St., Newton 64, Mass.*)

FOR THIS LITERATURE CIRCLE 171 ON READER-SERVICE CARD

Precision Stock Differentials

Features include: Four bevel gears & spider—stainless steel—eight precision bearings—choice of shaft diameter and length—angular displacement between



end gears 10′ of arc max. Bevel gears 303SS - 48DP - 36 T - 20° PA—(*From new 88-page Catalog E-88 and 16-page Supplement C, Dynamic Gear Co., Inc., 20 Merrick Rd., Amityville, L. I., N. Y.*)

FOR THIS LITERATURE CIRCLE 172 ON READER-SERVICE CARD

Optical Strain Gage

Makes possible the measurement of strains due to tension and compression as small as 0.000002 inch/inch on metals, brick, stone, concrete, plastics and many other materials at temperatures up to 1500°F.

The two basic units . . . operate jointly to measure strain of hot, cold, stationary or vibrating samples. The Extensometer is affixed to the sample under test . . . the autocollimator is positioned to observe deformation registered by the extensometer . . . A variety of knife edges are available to hold the extensometer correctly against the sample. The lozenge, with mirror surfaces, is held in place by spring action. As stress is applied, deformation of the sample causes the lozenge to rock. The degree of rocking is measured by the autocollimator . . . (*From new 8-page Bulletin 2294, American Instrument Co., Inc., 8030 Georgia Ave., Silver Spring, Md.*)

FOR THIS LITERATURE CIRCLE 173 ON READER-SERVICE CARD

Automated Teaching Device

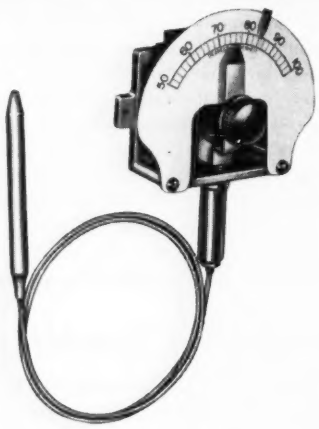
The Tutor is basically an automatic, random-access, recording microfilm-motion picture projector. In its simplest use the Tutor is a microfilm form of the scrambled book, with provision for recording the sequence of choices made by the student and the time spent on each. The student finds the first unit of information on image 1 of the microfilm, along with a multiple-choice question based on that unit of informa-

tion. As in the book, he selects the next image he will see by selecting an answer to the multiple-choice question. He enters the image number corresponding to his choice into the selector keyboard of the Tutor, presses the view button, and the device automatically locates and projects the image corresponding to the student's choice, and the printing recorder makes a record of the image number chosen and the elapsed time since the previous choice. If the student has chosen the correct answer to the multiple-choice question, the image he (thereby) selects will contain the next unit of information and the next question. If the student chooses an incorrect answer, the image he sees next will contain material designed to correct the particular error he has committed, will explain to him how to find the right answer, and will direct him to return to the first image to try again.—(*From new 45-page Booklet "Introducing the Western Design Tutor," Western Design Div., of U. S. Industries, Inc. Santa Barbara Div., Santa Barbara, Calif.*)

FOR THIS LITERATURE CIRCLE 174 ON READER-SERVICE CARD

NEW INDICATING TEMPERATURE CONTROL

Range Limits —100 to +600°F **E65N**



New Design gives maximum accuracy at low cost!

The UE Type E65N control is offered in basic skeleton form so that it may be easily incorporated, or designed into equipment, without the need and expense of an enclosure. Enclosures, however, are available upon specification. Setting and indication are clearly visible on a single scale allowing easy reference between the setting and controlling temperatures. Ideal for incubators, centrifuges, oxygen tents, sterilizers, and other applications where it is necessary to control and indicate temperature of gases, liquids and hot plates.

Temperature Ranges	A wide variety of scales between −100 & +600°F.
Thermal Assemblies	Standard 4' capillary with several bulb styles and sizes.
Operation	Liquid filled bellows assembly expands or contracts with heating or cooling thus actuating a snap-acting electrical switch at desired control point.
Switch Ratings	15 amps 115/230 volts AC. DC and other special switches available.
Switch Actions	Normally closed; normally open; and double throw, no neutral position.
Electrical Connections	Lead wires attached to terminal on switch.
Size & Weight	1 lb; scale plate 4½" wide.
Variations	Design variations available on request.

UNITED ELECTRIC *manufactures a complete line of temperature, pressure and vacuum controls. For application requiring custom-built units or modified standard units, call upon a UE application engineer for recommendations. Request Type E65N Design Catalog Sheet for complete specification and pricing data and for information regarding other United Electric temperature controls.*

United Electric Controls COMPANY

85 SCHOOL STREET, WATERTOWN, MASS.

CIRCLE 30 ON READER-SERVICE CARD

Solution Conductivity

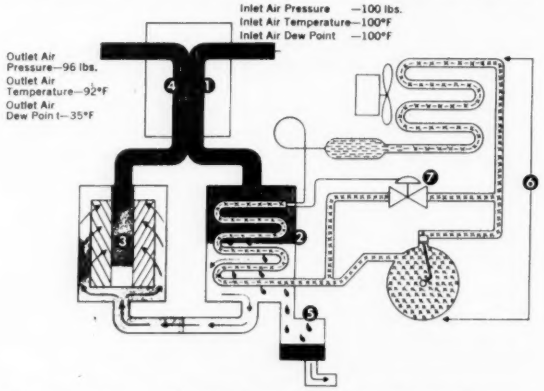
In all its forms, the Solu Bridge is a rugged electonic instrument for the measurement of electrolytic or solution conductivity. The measuring circuit is a true A.C. Wheatstone Bridge utilizing an electron ray "eye" tube as the null indicator and is independent of voltage fluctuations or vacuum tube characteristics. Each Solu Bridge is provided with two scales; the upper, calibrated in conductivity, resistivity or concentration of a specific electrolyte, and the lower, calibrated in temperature and constituting the manual temperature compensator.

The RE and REI Solu Bridges contain, in addition to the Wheatstone Bridge measuring circuit and "eye" tube null indicator described above, a vacuum tube relay circuit which operates on the bridge unbalance voltage and provides 115V AC up to 1 ampere (non-inductive) for operation of a warning signal or other electrical device. When the conductivity of the solution under test passes through the value corresponding to the dial setting, the powered SPDT relay will throw . . . (*From new 28-page Booklet 14479 D, Industrial Instruments, Inc., 89 Commerce Rd., Cedar Grove, N. J.*)

FOR THIS LITERATURE CIRCLE 175 ON READER-SERVICE CARD

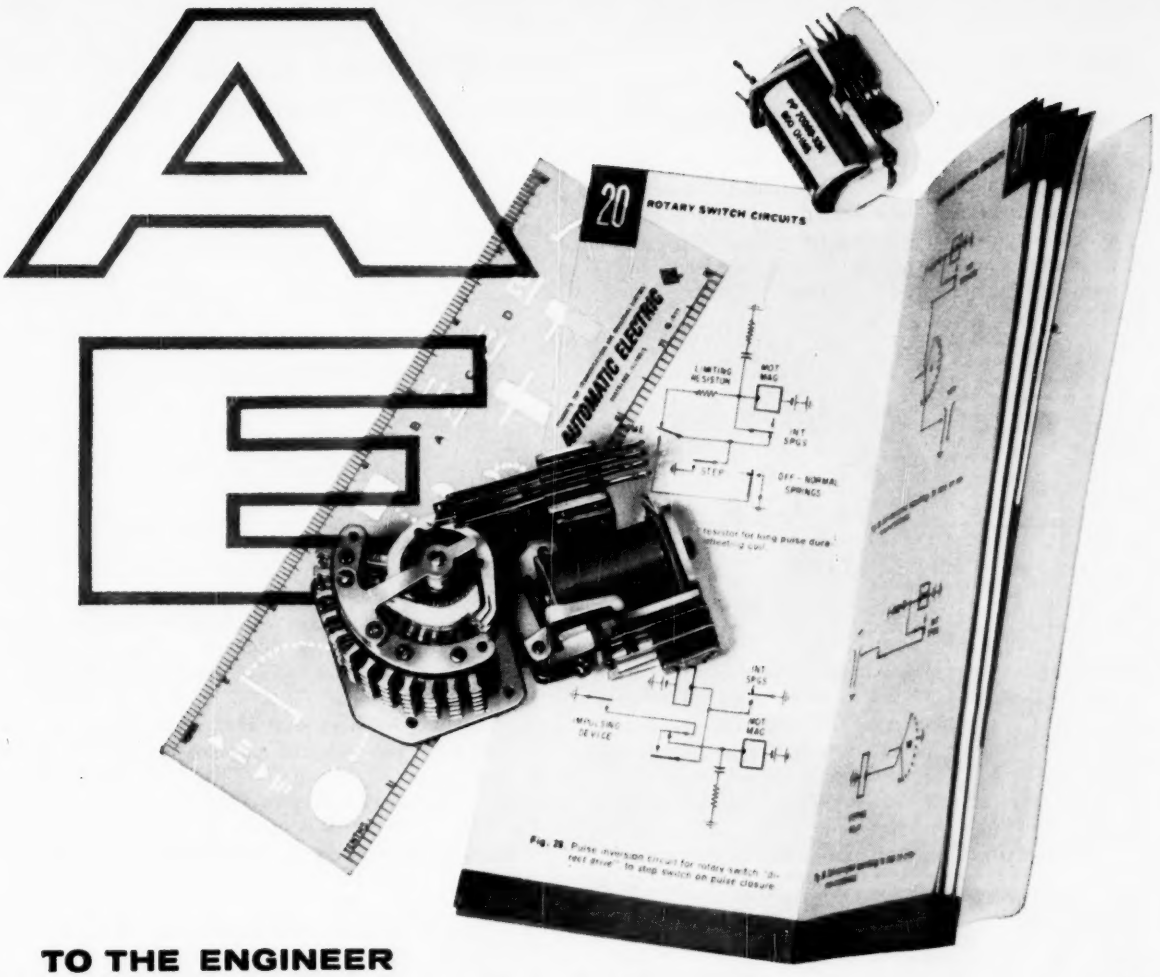
Engineered Dehydration by Refrigifilter

(1) Hot, saturated air enters the unit and immediately passes through the heat exchanger. Here a precooling process is performed to begin lowering the dew point of the air and begin condensing out oil and moisture vapors. (2) After circulating through the



Heat Exchanger, the air flows down into the condenser-evaporator. Here the final cooling of the air takes place . . . (3) The moisture-free and oil-free air now passes up through the felt filter cartridge element . . . (4) Leaving the filter cartridge, the cool, dry air reenters the heat exchanger where it is reheated by the incoming "hot" air, before entering the lines. By reheating the air, "sweating" is prevented and the relative humidity is reduced since reheating increases the air's capacity to hold water vapor . . . (*From new 4-page Bulletin F-100, Hankison Corp., College & Pike, Canonsburg, Penna.*)

FOR THIS LITERATURE CIRCLE 176 ON READER-SERVICE CARD



TO THE ENGINEER

who needs "for instances"

Take such a "for instance" as this: you want to step an indirectly driven rotary switch immediately on pulse closure. The schematic, Fig. 28, above, points out an easy way of doing it with a standard relay.

Or suppose you'd like to stretch a pulse with a relay—or set up a sequential programming circuit with stepping switches. You'll find the most practical methods among the 41 schematics in AE's new 32-page booklet on "Basic Circuits." It comes complete with a handy template for drawing relays and switches on your own circuits. And it's all yours for the asking!

In case you don't find the solution to your switching problem in *Basic Circuits*, our engineers can find a solution for you. In fact, AE engineers can show you switching tricks that will cut corners on costs. Or, if you wish, they'll assume the job of designing and building to *your* specs, anything from a simple control package to an entire system.

To get your copy of *Basic Circuits* and/or the answer to your specific control problem, just write J. E. James, Director, Control Equipment Sales, Automatic Electric, Northlake, Ill. In Canada: Automatic Electric Sales (Canada) Ltd., 185 Bartley Dr., Toronto 16, Ont.

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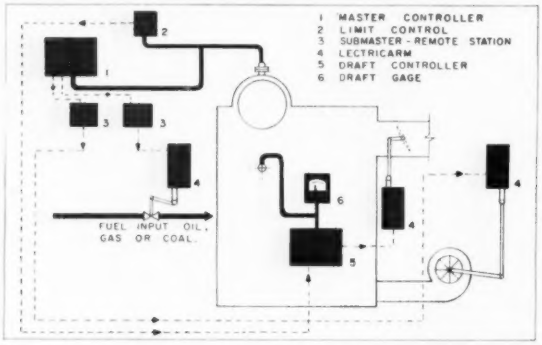
CIRCLE 31 ON READER-SERVICE CARD

BRIEFS—CONTINUED

Combustion Controller

The Master Controller is a fully automatic, heavy-duty sensing and controlling instrument, for use with semi-automatic and full-automatic combustion control system or comparable industrial applications . . . By means of a bellows or other sensing elements as required, the boiler header pressure (in steam control-

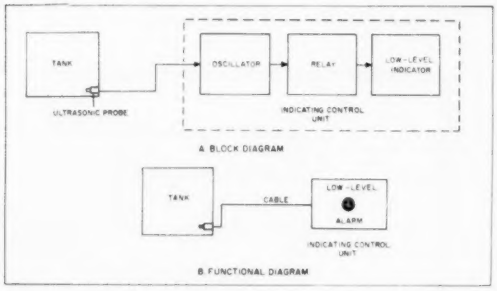


lers) or the water temperature (in temperature controllers) is caused to react on sensitive balancing switches. A signal is transmitted to other controllers and actuators for continuous and accurate re-positioning and regulation . . . (*From new Catalog CMC-687, Cleveland Controls, Inc.*, 1111 *Brookpark Rd., Cleveland 9, Ohio.*)

FOR THIS LITERATURE CIRCLE 177 ON READER-SERVICE CARD

Ultrasonic Liquid Level Switches

Acoustica's miniaturized, hermetically sealed ultrasonic probe is sensitive to the presence or absence of liquids . . . The control circuit consists of a transistorized oscillator and a subminiature relay. The piezo-



electric element inside the probe tip and the associated circuit in the control unit function effectively as a crystal oscillator. When liquid surrounds the probe tip, the circuit does not oscillate because of the damping effect of the liquid . . .

Ultrasonic switching units afford an efficient method monitoring the correct sequence of valves in the piping system . . . (*From new 36-page Document DO 550A, Acoustica Associates, Inc., Fairchild Court, Plainview, L. I., N. Y.*)

FOR THIS LITERATURE CIRCLE 178 ON READER-SERVICE CARD

ARE YOU PROPERLY GEARED FOR

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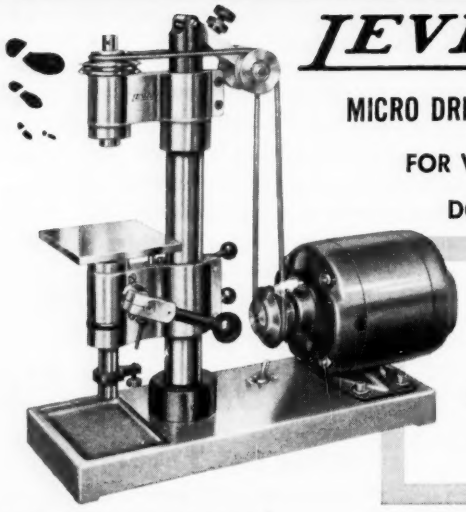
SMALL DRILLS MUST BE HELD IN PRECISION COLLETS TO ASSURE ACCURACY



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FOR VERY SMALL HOLES DOWN TO .002"

A super-sensitive drill press in which drills are held in precision collets to eliminate chucking errors. Table is keyed to prevent any play. Feed is by raising table. No quill to cause drag.

For complete details of Micro-Drilling equipment send for catalog T.

Louis Levin & Son, Inc.
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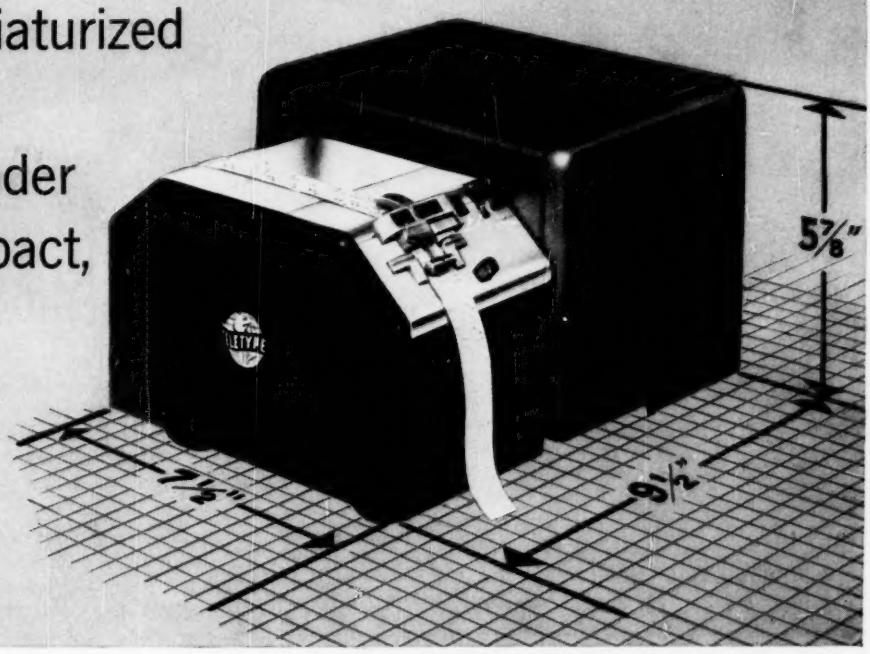
Los Angeles 7, Calif.

CIRCLE 32 ON READER-SERVICE CARD

40% reduction in size and weight...

New miniaturized Teletype Tape Reader has compact, space-saving design



Here is a new tape reader set from Teletype Corporation—the Model 28 miniaturized LXD. It features a 40% reduction in size and weight. This new space-saver set is completely compatible with other Teletype communications equipment. It features facilities for sequential (serial) transmission, with optional contacts available for multi-wire output, and it is designed to read either chadless or fully perforated tape.

The Model 28 miniaturized LXD tape reader is made, as is all Teletype equipment, for round-the-clock, day-in, day-out service with minimum maintenance. The unit is equipped with an all-metal clutch that requires lubrication only once or twice a year, and operates with precision accuracy for continuous or intermittent transmission.

New Brochure A 4-page brochure on the new Teletype miniaturized LXD tape reader is available upon request. Write to Teletype Corporation, Dept. 27A, 4100 Fullerton Ave., Chicago 39, Ill.

Specifications

Speed:	100 WPM (gears available for slower speeds)
Tape levels:	5 or 6
Dimensions:	5⅞" H, 7½" W, 9½" D.
Weight:	Approx. 15 lbs. net
Motor:	Synchronous, 115 V., 60 Cy.
Finishes:	Gray-green or custom

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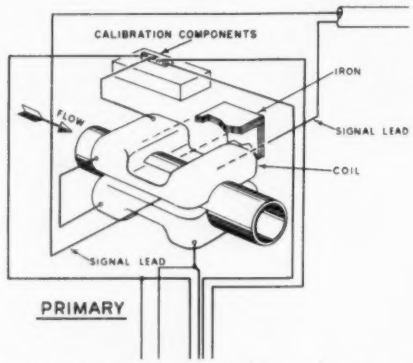
CORPORATION
SUBSIDIARY OF *Western Electric Company* INC.

CIRCLE 33 ON READER-SERVICE CARD

Magnetic Flowmeter

The F&P Magnetic Flowmeter operates as a simple a-c generator in which the flowing fluid is the armature and the electrodes act as brushes. The field is an externally generated, extremely uniform parallel magnetic field . . . Movement of a conductor at right



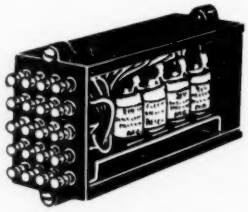
angles through a magnetic field produces a voltage in a plane mutually perpendicular to the field and to the direction of movement. The voltage produced is directly and linearly proportional to the velocity of the conductor (the velocity of the flowing fluid in the case of the magnetic meter).

Since, with a given pipe size, the volumetric flow rate is dependent solely on flow velocity, the induced voltage is also directly proportional to volumetric flow rate . . . (*From new 6-page Catalog* 10*D*1416, *Fischer & Porter Co., Hatboro, Penna.*)

FOR THIS LITERATURE CIRCLE 179 ON READER-SERVICE CARD

Bina-Dec Decoder

Despite the increased use of automatic data handling by industry, there is a continuing need for a human operator or supervisor to interpret the information being processed by such machines. This information is usually in the form of printed or illuminated letters or numbers, and may represent gallons per minute, pressure, elapsed or remaining time, etc., depending upon the process under control. Unfortunately for the operator, his machine will probably op-



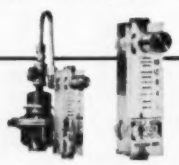
erate on binary coded data while he is accustomed to the decimal form. This suggests the need for a compact binary-to-decimal converter . . . A relay tree is used to perform the translation, with the actual number of relays depending upon the code used. Four or five terminals plus a common terminal are provided for input information to control the relays . . . (*From new binder containing 8 bulletins, price lists and instruction sheets, Industrial Electronic Engineers, 3973 Lankershim Blvd., North Hollywood, Calif.*)

FOR THIS LITERATURE CIRCLE 180 ON READER-SERVICE CARD

Low Cost PURGE METERS

***Simple *Safe *Sure**

New Series C M acrylic plastic PURGE METERS have been developed for all purging applications requiring a positive flow indication and maximum reproducibility of small flow conditions. Drilled, reamed and polished, these precision engineered units provide the ideal method of inexpensively measuring small gas or liquid flows where high accuracy is not paramount. Etched scales permit direct, easy readings and advanced flow control valve offers improved convenient control. Solid, one piece construction insures trouble-free operation. From $5.00.



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CIRCLE 34 ON READER-SERVICE CARD

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CIRCLE 35 ON READER-SERVICE CARD

Information Systems

The Metrotype Information System . . . is essentially a system to sequentially select analog signals, measure them, and convert them to digital form. It may also log the numerical values on typed pages, indicate the measurements on numerical lamps, store the information on punched tape, or compare the measurements as they are made against preset high or low limits for detection of off-normal conditions. These principle functions are available individually or combined as required to meet the particular application requirements . . .

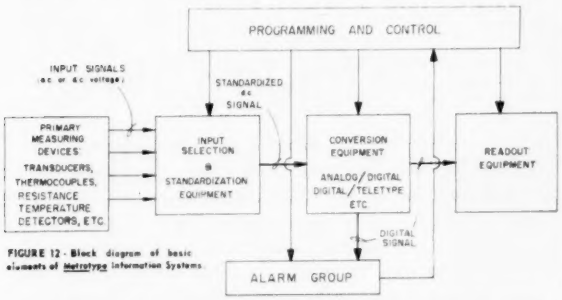


FIGURE 12 - Block diagram of basic elements of Metrotype Information Systems

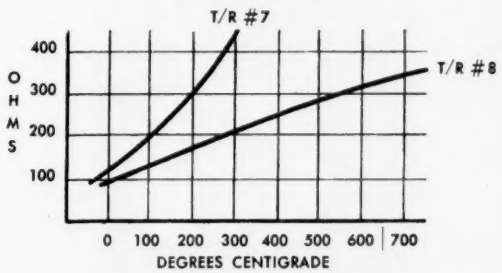
Completely solid-state electronic equipment is used where high speed and high duty cycle demand it; proven electro-mechanical equipment may be used where economically desirable . . . (*From new 8-page Form BE72-2, Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland 10, Ohio.*)

FOR THIS LITERATURE CIRCLE 181 ON READER-SERVICE CARD

Resistance Temperature

Resistance Temperature Detectors operate on the simple principle that the electrical resistance of a metal increases with temperature.—The use of a relatively high basic resistance and voltage in Edison RTD's provides sufficient power to operate an indicator or relay without the aid of amplifiers. The platinum

for reference only



wire resistance temperature detector, for example, is so reliable that it is the International Temperature Scale used by the U. S. Bureau of Standards for measuring temperatures between minus 300°F and plus 1165°F . . . It is now readily possible, under properly controlled conditions, to produce interchangeable resistance temperature detectors that are stable over many years of use . . . (*From two new 8-page Bulletins 3047 and 3016 E, Thomas A. Edison Industries, Instrument Div., West Orange, N. J.*)

FOR THIS LITERATURE CIRCLE 182 ON READER-SERVICE CARD

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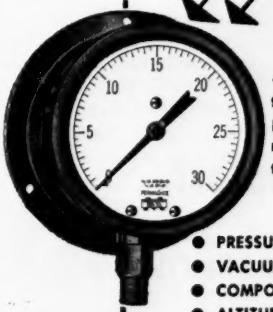

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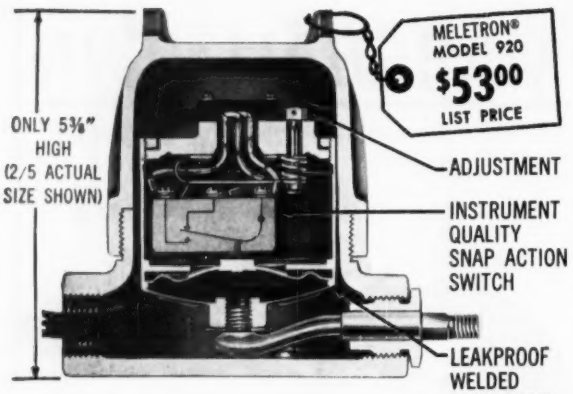
LEPEL Electronic Tube GENERATORS—1 KW; 2½ KW, 5 KW; 10 KW; 20 KW; 30 KW; 50 KW; 75 KW; 100 KW.
LEPEL Spark Gap Converters 2 KW; 4 KW; 7½ KW; 15 KW; 30 KW.

WRITE FOR THE NEW LEPEL CATALOG . . . 36 illustrated pages packed with valuable information.

All Lepel equipment is certified to comply with the requirements of the Federal Communications Commission.

LEPEL HIGH FREQUENCY LABORATORIES, INC.
55th STREET and 37th AVENUE, WOODSIDE 77, NEW YORK CITY, N. Y.

CIRCLE 37 ON READER-SERVICE CARD



Here's the Simplest Diaphragm Pressure Switch for Explosive Atmospheres

WE BUILD IN	WE DON'T USE
EXTREME ACCURACY and DEPENDABILITY maintained during operating life due to direct acting design	LINKAGES & BEARINGS which, as they wear, make the setting of the pressure switch drift.
OPERATION IN ANY POSITION which saves the installation costs encountered in mounting a switch that uses liquid switching elements	LIQUID SWITCHING ELEMENTS which make the switch difficult to mount and very critical to vibration.
IMMUNITY TO VIBRATION you can mount the switch directly on your vibrating or moving equipment.	ACCORDION BELLOWS which make the pressure switch sensitive to vibration.

ASK FOR NEW CATALOG 9-PS FREE

PRESSURE SWITCH DIVISION

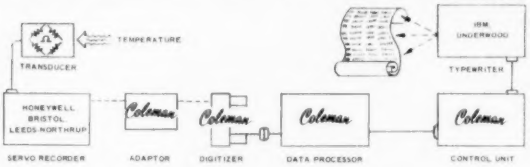
Barksdale valves

5125 Alcoa Avenue, Los Angeles 58, California

CIRCLE 38 ON READER-SERVICE CARD

Absolute Positional Encoders

It is possible to classify these instruments (absolute positional encoders) into three distinct categories: (1) mechanical cam encoder, (2) electrical or optical commutator encoders, and (3) decimal contact encoders . . . Mechanical cam encoders define the position of a shaft rotation by a specific configuration of cam positions . . . An electrical commutator encoder resolves the value of angular shaft position by placing a group of pick-off brushes against a mechanical rotor



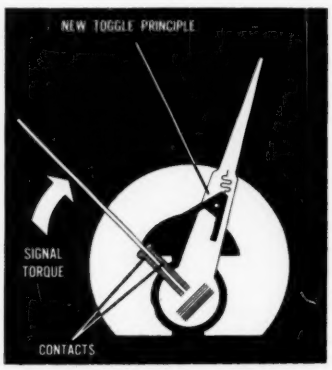
whose surface carries some unique configuration of conducting and insulated commutator segments.

A second major type of commutator encoder in present use is the optical commutator. This encoder uses a disc which provides a pattern of transparent and opaque segments that are resolved by an array of photocells and collimated light sources . . . (*From new 72-page Catalog 60A, Coleman Electronics, Inc., 133 East 162nd St., Gardena, Calif.*)

FOR THIS LITERATURE CIRCLE 183 ON READER-SERVICE CARD

Continuous Reading Meter-Relay

The key to the new design principle of the CRMR is a toggle in the shape of an inverted V which holds two contacts. One contact faces upscale; the other faces downscale. The toggle is pivoted on the set-point arm, and, like the set-point arm, is composed of a laminate of two metal strips isolated by a center



strip of insulation. This permits each toggle contact to form a separate circuit. The measuring element in the CRMR is a D'Arsonval movement with a signal coil and indicating pointer. Two contacts are mounted on the indicating pointer. Two additional coils (boosters) are wound with the signal coil. While the measured variable is at a normal level, only the signal coil is energized . . . (*From new 4-page Bulletin S-2, Assembly Products, Inc., 75 Wilson Mills Rd., Chesterland, Ohio*).

FOR THIS LITERATURE CIRCLE 184 ON READER-SERVICE CARD

NOW! 2 GREAT NEW AMPLIFIERS

Model A14—High input source impedance for operational applications.

Model A15—Noise level less than 1 microvolt!

Model A12's pass rugged military environmental tests for altitude, shock, temperature, humidity and electro interference.

Design and construction techniques used in the Model A12 amplifier are fully two years ahead of the field! These advanced techniques enabled the Model A12 to meet stiff environmental qualification tests which resulted in their being selected by Martin engineers for use in the *Titan* ground support equipment.

Use of totally transistorized circuits gives the A12 unmatched reliability and performance, and minimizes heat dissipation problems inherent in vacuum tube instruments. Plug-in etched circuit boards and modular internal construction make servicing and maintenance checks easy—the amplifier can be disassembled and reassembled in less than 10 minutes. *Your E-I representatives can give you complete information.*

Martin picks Electro Instruments D.C. Amplifiers for TITAN ground support equipment

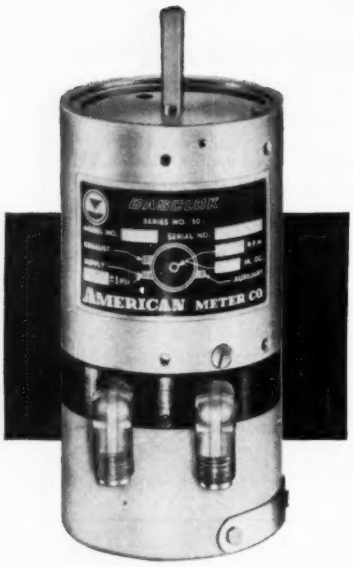
Plug-in attenuators of the A12 provide convenience, flexibility, economy. Special variations, gain settings, etc., can be tailored to your system at no extra cost.

- Totally transistorized—dissipates only 7 watts.
- Drift less than 2 microvolts for 200 hours.
- .01% linearity and stability.
- 100 megohms input impedance—40 milliohms output impedance.
- 1 db DC to 10 KC.
- Noise less than 10 microvolts wideband.
- Single ended or differential input.
- Operates to specifications from 0° to 50°C.
- Self-contained power supply—operates on any line frequency from 50-400 cps.
- Mil-type chopper gives unmatched reliability for the life of the instrument.
- 7" x 19" panel accommodates 8 instruments.

Electro Instruments, Inc.

3540 AERO COURT
SAN DIEGO 11, CALIF.

CIRCLE 39 ON READER-SERVICE CARD



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GASCLOK

POWER

DRIVE

Completely self-contained gas or air-powered instrument driving and timing unit for long, trouble-free operation in remote locations. The GASCLOK delivers more than 20 times the torque of conventional spring-wound mechanisms. Continuous timing accuracy is unaffected by a ± 20% variation in supply pressure.

Inherently explosion proof and self-starting, the GASCLOK is ideal as original or replacement equipment for strip chart and conventional circular chart instruments. The timing mechanism is internally sealed to prevent corrosion, and all power unit parts exposed to gas are aluminum or stainless steel. Large area internal ports prevent clogging. Normal air or gas consumption 5 cfh . . . operating pressure 5 psi . . . rotation 2 rpm.

AMERICAN®
METER COMPANY
INCORPORATED (ESTABLISHED 1836)

Executive Offices: Philadelphia 16, Pa.
Sales offices in principal cities.

CIRCLE 40 ON READER-SERVICE CARD

ICS PANHANDLE PETE

Annual Report From Wesco!

Annual Report:

Division	Income	Expenses	Percent change in Income over Previous year
System Systems Div.	$ 147,000	$3,743,000	+242%
Systems Div.	$ 342,000	$2,148,000	+182%
Industrial Div.	$ 474,000	$ 475,000	+ 15%
Himmelraket Div.—Anaheim	$2,147,000	$ 343,000	+87.5%
Small-Firm Automation Div.	$3,742,000	148,000	− 4.2%
	$6,852,000	$6,857,000	

At year end it is appropriate to give a Financial report on our various operations, including the various divisions of WESCO!

Systems Division and **Systems Systems Division** (supplying systems to systems that need systems) showed the greatest growth for the year—182% in the former and 242% in the latter over previous-year figures. Great interest in systems by all editors means that this market should increase 187.2% next year.

Industrial Division increased 15% over previous year. However, this market is expected to shrink as nobody is paying any attention to it at all. Retrenchment is indicated.

Himmelraket Division showed annual increase of 87.5%, exactly as it has done every year since 1952. Increase in 1960 over 1959 is expected to be 87.5%. This phase of our industry is very stable.

Small-Firm Automation Division is slipping as its volume declined 4.2% owing to declining demand for screwdrivers, counters and rotameters. Trend is definitely away from small products to large systems.

Plans for 1960:

1. Owing to decline of 4.2% in Small-Firm Automation Division, a staff cut will be made; all funds for promotion of this division will be cut.

2. Owing to large percentage increase in the Systems Divisions, these will be expanded and all promotion budgets for these divisions will be expanded.

3. Total volume of business will support a $1 million bank loan to expand our Systems Divisions, each of which will get a new building to house expanded staff.

Panhandle Pete

Editor, I&CS:

In number 4, 1959 *I&CS* Panhandle Pete gave a report of Mr. Klappsaddle's trip to Russia. It seems very interesting reading the different opinions on education of scientists. If you will have success with your propositions is doubtful. But (Photo 2)—Please be so kind and write me the names of countries where secret policemen are in uniforms!

Fr. Frohlich
Berlin

Russian secret policeman observes suspicious cookies.

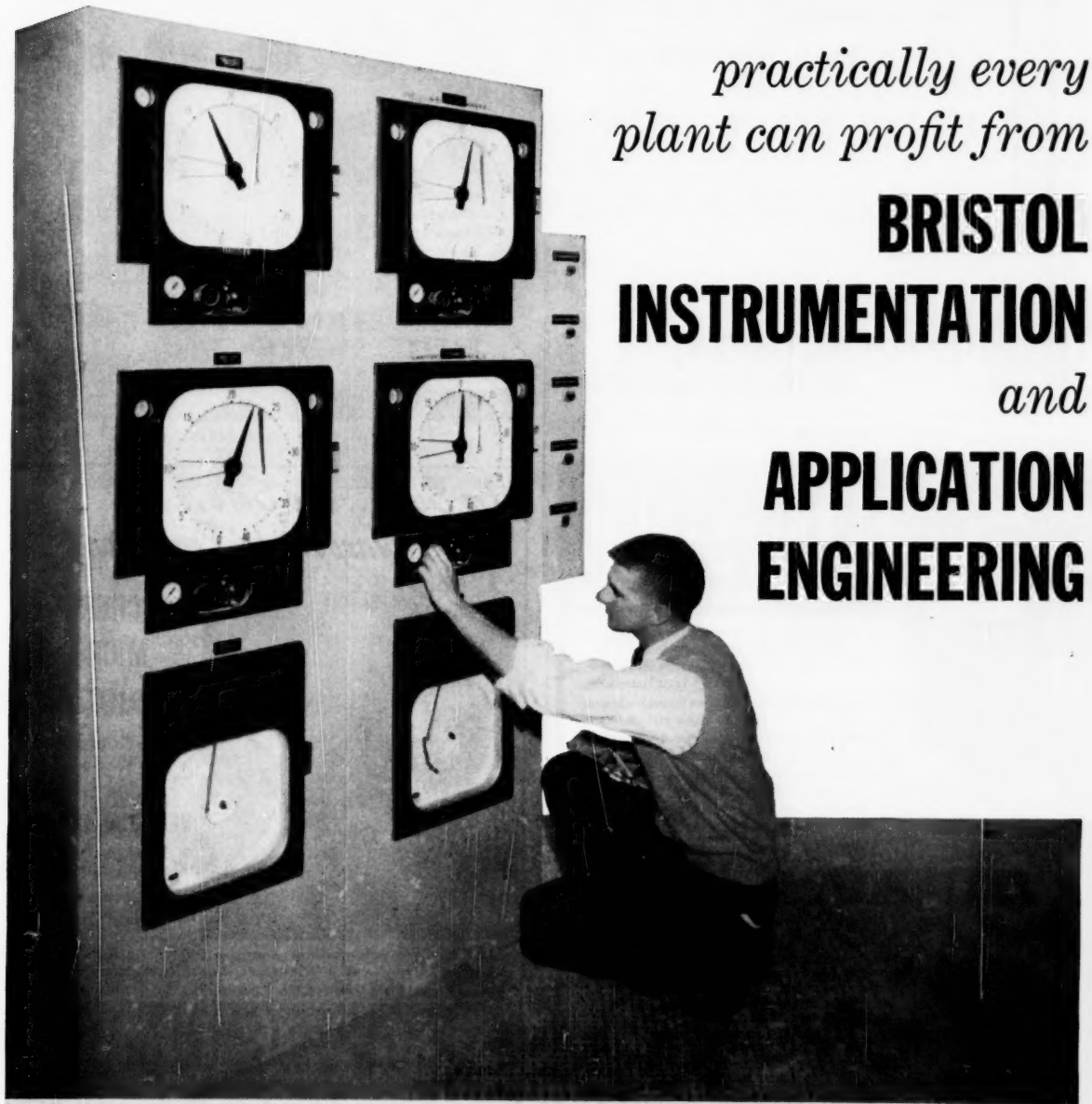
Name your process; Bristol can help you measure, record or automatically control it.

Just one example: Wood Conversion Company's new Riverside, N. J., plant with an all-Bristol process instrument installation, part of which is shown below. Here precise instrument control helps turn out, in a wide variety of forms, Balsam Wool® for housing insulation and Tufflex® used for cushion padding, sound deadening, and protective packaging. Costly human errors are eliminated, improving product uniformity and releasing valuable supervisory time for more important duties.

Whatever your plant or process, Bristol engineers —as at Wood Conversion—are always ready to work with your engineers in setting up a new instrumentation system or in modernizing and improving your existing system.

Temperature, pressure, absolute pressure or vacuum, flow, liquid level, humidity, pH, tension, thickness, speed and mechanical motion are just a few of the variables that can be recorded or exactly controlled.

Bristol makes the most complete line of instruments on the market—full-size, miniature, electronic and pneumatic types—for measurement, recording, automatic control and telemetering. Bristol's wide line insures you of the right instrument for your job, every time, and Bristol engineers are always ready to assist you in selecting it. Write: The Bristol Company, 113 Bristol Road, Waterbury 20, Conn. 9.24



practically every plant can profit from

BRISTOL INSTRUMENTATION *and* **APPLICATION ENGINEERING**

BRISTOL...for improved production through measurement and control

AUTOMATIC CONTROLLING, RECORDING AND TELEMETERING INSTRUMENTS

Come in and see us at Booth 320 at the Houston ISA Show

CIRCLE 41 ON READER-SERVICE CARD

Buy ONE Manometer
Use it for ALL FLUIDS!

- Dynametrics U-Tube and Single Tube precision-built Manometers feature universal compatability with every manometer fluid. No need to change wetted parts when fluids are changed.
- Wetted parts of Pyrex, stainless steel, and non-deteriorating seals will not corrode in presence of water, mercury, TBE, hydrocarbons.
- 8 U-Tube models, scale heights ±3" to ±25"
- 13 Single Tube models, scale heights 6" to 100"

Large multitube and photopanel units also available for maximum utility in minimum space.

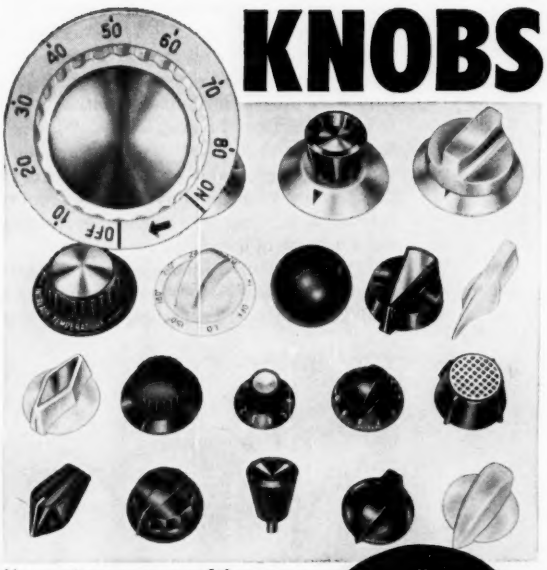
Write for Dynametrics "Pressure Measuring Instruments" Catalog

DYNAMETRICS CORPORATION

Northwest Industrial Park, Dept. 18, Burlington, Mass.

CIRCLE 42 ON READER-SERVICE CARD

KNOBS



Shown above are some of the many Rogan knobs available from stock molds. Fast delivery. Special shaft holes at nominal cost. Send for details and catalog.

FROM STOCK MOLDS OR CUSTOM MOLDED TO YOUR OWN DESIGN

ROGAN BROTHERS

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AMERICA'S FOREMOST MOLDERS AND BRANDERS OF PLASTIC KNOBS

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Thermophil
THERMISTOR THERMOMETERS

- ACCURACY (of complete system): 1/3% to 2/3% of total Scale Range. Readability: .5 F° on 400 F° span instruments. .1 F° on 55 F° span instruments.
- SCALE LENGTH: 8-1/2" on three overlapping scales; 11-1/2" on four scale instruments.
- FASTEST RESPONSE: .7 sec. time constant in liquids; 2.2 sec. on surfaces.
- ONE HUNDRED INTERCHANGEABLE PROBES, TWENTY-SIX INSTRUMENTS, Readings between —148° F and +845°F or —100° C and +450°C.
- BATTERY or AC powered.
- STABLE EUROPEAN THERMISTOR resistance element, bridge circuit and amplifier.

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Shell; G. E.; Westinghouse; Harshaw Chemical; Goodyear Aircraft; Union Carbide; A.E.C.; Gulf; U. S. Steel; Crucible Steel; duPont; G.M.; Goodrich Chemical; Standard Oil of Ohio; General Tire; Industrial Rayon; Bausch & Lomb; Remington Arms; Western Electric; U. S. Department of Agriculture; Universities and Independent Laboratories...

INTRODUCTORY OFFER

COMPLETE $180.00

Satisfaction Guaranteed

Instrument as pictured, °F. or °C.
Temperature range; overlapping:

	Model #4412F	Model #4412C
Scale I	32° to 158°F	0° to 70°C
Scale II	158° to 284°F	70° to 140°C
Scale III	284° to 410°F	140° to 210°C

with one probe, choice of #H10AO stainless steel for surfaces, #H01AF glass tipped for liquids, #H12AF stainless steel needle

ATKINS TECHNICAL, INC.

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Cleveland 13, Ohio • Telephone: SU 1-1333

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Be Sure... Be Safe...
Inspect by Projection!

SCHERR MICRO PROJECTOR

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with the

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For Complete Information request our 96 Page Catalog — Contact any of our 4 "Coast to Coast" Locations or your nearest Local Distributor.

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NEW YORK: 200 Lafayette Street, New York 12, N. Y.
ST. JAMES: St. James, Minnesota
LOS ANGELES: 3337 West Olympic Blvd., Los Angeles 19, Cal.
CHICAGO: 5045 W. Harrison, Chicago 44, Ill.

When writing to any of the above locations, refer to DEPT U-1

CIRCLE 45 ON READER-SERVICE CARD

• Inserts match thermocouple alloy
• Inserts easily interchangeable
• Color coded discs for easy calibration identification
• Number discs for easy identification of individual T/C's

NEW *QuiK-Konnect** thermocouple components

For accurate, swift, and foolproof connection of thermocouples to extension wire

New *QuiK-Konnect* plug and jack bodies give fast, easy, and foolproof extension wire connections in plant, laboratory or test cell installations.

Inserts have different diameter positive and negative poles, for foolproof connection . . . are extremely easy to remove for field calibration change or replacement. Various tube adapters are available to protect small-diameter thermocouples, and cable clamps can be supplied to protect extension wires from fraying or tearing.

The *QuiK-Konnect* line, in addition to plugs and jacks, includes:

1. Single-jack panel that fits ¾-in. knockout.
2. 4-point jack panel that fits standard electrical outlet box.
3. Multiple jack strips.
4. Custom-built multiple jack panels.
5. *QuiK-Kords** for patch programming multiple jack panels.

You can get complete details from your nearby Honeywell field engineer. Call him today . . . he's as near as your phone.

MINNEAPOLIS-HONEYWELL, 21 Penn St., Fall River, Mass.

*Trademarks

75th YEAR PIONEERING THE FUTURE

Honeywell

First in Control

SINCE 1885

CIRCLE 46 ON READER-SERVICE CARD

King MANOMETERS

For Plant and Laboratory

King Manometers are rugged, low-cost instruments of unexcelled accuracy for measuring pressure, vacuum, differential pressure, and pressure-related phenomena. They're available in the following types, in a complete range of sizes:

U-Type Manometers

- Single Cleanout
- With 3-Valve Manifold
- Double Cleanout
- Inverted U-Type

Well-Type Manometers

- Low-well
- Barometric-Reading
- Raised-Well
- Flowmeter Type
- Adjustable-Well
- Inclined-Tube

Multi-Tube Manometers

- Individual-Well
- Common-Well
- Photo-Manometers

NEW CATALOG 2008 gives details on these and other models—includes manometer liquids and accessories—explains basic principles. Write—

I/C INSTRUMENTS

KING ENGINEERING CORP.

Box 70 • Ann Arbor, Mich.

REPRESENTATIVES IN PRINCIPAL CITIES

CIRCLE 47 ON READER-SERVICE CARD

OPTICS BUILT

A. D. JONES OPTICAL WORKS

2400 MASSACHUSETTS AVENUE
CAMBRIDGE 40 MASSACHUSETTS

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A LIST OF MATERIALS WE FABRICATE USED IN OPTICS AND ELECTRONICS

SAWING GRINDING POLISHING DRILLING

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BARIUM TITANATE
BISMUTH
BRASS
CARBORUNDUM
CERAMIC
COBOLT FERRITE
COPPER
*CORNING 707
*CORNING 7052
CUPROUS BROMIDE
FERRITE
FERROX
**FLUORIDE, CALCIUM
**FLUORIDE, LITHIUM
GALLIUM ANTIMONIDE
GALLIUM ARSENIDE
GARNET
GERMANIUM
GOLD
INDIUM ANTIMONITE
INDIUM PHOSPHIDE
INDOX
IRON SINGLE CRYSTAL
LITHIUM FERRITE
MAGNETIC PLUMBITE
MELAMINE FIBER GLASS
MICA, SYNTHETIC
NICKEL OXIDE
PLATINUM
POTASSIUM BROMIDE
*PYREX
*QUARTZ, CRYSTAL
*QUARTZ, FUSED
**SAPPHIRE
**SODIUM CHLORIDE
**STEEL
STRONTIUM TITANATE
TEFLON
TITANIUM DIOXIDE
*VYCOR
*X-RAY LEAD GLASS
ALL TYPES KNOWN GLASS

* Carried in stock
** Purchased for orders

CIRCLE 48 ON READER-SERVICE CARD

ICS STOCK REPORT

Further information may be obtained from the Research Department, Bache & Co., 36 Wall Street, New York 5, N. Y.

NEW YORK STOCK EXCHANGE

PRICE RANGE FOR 1959 THRU DECEMBER 19, 1959

	High	Low	Price As Of 12/17/59
ACF Industries	57	46 1/4	50 1/4
Aeroquip Corp.	34 3/4	23 5/8	32 3/4
Allis Chalmers	38 3/4	26 7/8	34 1/4
American Chain & Cable	61 3/4	47 3/4	50
American Machine & Foundry	52 3/8	45 1/8	49
Amer. Mach. & Metals	59 3/4	41	57
American Optical	53 1/2	38 3/8	48 3/4
Amer. Tel. & Tel.	89	75 1/8	76 1/2
Ampex Corp.	137	61 1/4	119 3/4
Bausch & Lomb Optical	41 1/2	27	38 7/8
Beckman Instruments	74 3/4	36 1/4	64 1/8
Bell & Howell	77 3/8	53 1/4	74 3/8
Bendix Aviation	89	61	72
Boeing Airplane	46 1/2	29 1/8	30 3/4
Ballard	24 7/8	15 1/2	17 1/4
Bulova Watch	20 5/8	13 3/8	16 1/2
Burroughs	45 3/4	28 3/4	35 1/8
Carborundum	56 3/4	37 3/8	52
Cincinnati Milling Machine	47 5/8	35 1/4	40 1/4
Clevite	59 1/4	24 3/4	54
Columbia Broadcasting System	48 3/4	35	42
Con. Electrodynamics	45 1/2	30 3/4	40 3/4
Consol. Electronics	58 7/8	37 1/4	52 3/8
Cornell Dubilier	30 1/2	17 3/4	22
Corning Glass	154 3/4	89 3/4	143 1/2
Curtiss Wright	40 3/4	27 1/8	30 5/8
Cutler - Hammer	94 3/4	54 1/2	92 1/2
Dyastrom	49 3/4	34	40
Douglas Aircraft	59 3/4	36 7/8	38 1/2
Eastman Kodak	112	75	109 3/4
Eaton Mfg.	44 3/4	36 3/4	43 1/2
Electric Auto-Lite	55 1/2	36 1/4	54 1/4
Elgin Watch	14	9 3/4	12 7/8
Emerson Electric	77 1/2	48 1/8	74 1/4
Food Mach. & Chem.	55 3/8	40	49 3/4
Garrett	50 7/8	38	43 3/4
General Controls	39 1/4	24	26 3/4
General Dynamics	66 1/2	42 7/8	47 3/8
General Electric	97 3/4	74	93 1/2
General Instrument	38 3/8	16 1/2	30 1/8
General Mills	37 5/8	30 1/2	31 7/8
Gen. Precision Equip.	60	31 1/2	56 3/4
Gen. Railway Signal	39 1/4	26 3/4	31 3/4
Gen. Tel. & Elect.	85 1/8	60	83 1/4
General Time	104 1/2	35	90
General Tire & Rubber	86 3/4	44 1/8	81 1/8
International Bus. Mach.	488	305 1/2	433
Internat'l. Tel. & Tel.	45 1/2	28	38 1/2
I-T-E Circuit Breaker	50 1/2	36 5/8	B 41 1/2-A 41 5/8 (1)
Lear Inc.	23 1/4	9 1/8	19 3/8
Litton Industries	150 3/4	72 5/8	135
Lockheed Aircraft	39 3/4	24 5/8	32 1/8
Magnavox	40 3/8	32 3/4	37 5/8
Mallory	48 3/4	35 3/4	49
Minneapolis-Honeywell	150	111 1/2	139
Minnesota Mining & Mfg.	178 1/4	111 1/2	166 3/4
Motorola	165 1/4	57 1/2	151 3/4
National Acme	63 1/2	50 1/8	54 1/4
National Cash Register	80	55 1/8	65 3/4
Neptune Meter	39 5/8	27 3/4	31
North American Aviation	52 5/8	30 1/4	33 7/8
Northrop Aircraft	44 3/4	24 5/8	28 3/8
Otis Elevator	88 1/4	61 1/2	82 1/2
Philco Corp.	36 3/4	21	33 3/4
Radio Corp. of America	73 1/4	43 1/8	68 1/2
Raytheon Mfg.	73 7/8	43 1/2	52 3/4
Reliance Electric	73	42 5/8	69 1/2
Rheem Mfg.	29 1/4	17 3/4	29 1/8
Robertshaw Fulton	59 3/4	31 5/8	58 1/8
Royal McBee	24 3/8	16	19 1/2
Sangamo Electric	51 1/2	35	41 1/2
Siegler Corp.	45 1/8	23 1/8	33 7/8
Sperry Rand	28 1/4	21 1/8	26 1/8
Square D	37 1/4	26 7/8	36
Standard Coil Products	23 3/4	13 3/4	15 3/4
Starrett (L.S.)	23 7/8	19 3/4	20
Stewart-Warner	65	42 1/2	65 1/4
Telautograph	13 3/8	8 5/8	9 1/8
Texas Instruments	193 1/2	61 1/4	168 3/4
Thompson-Ramo-Wooldridge	70 1/4	52	60
Tung-Sol Electric	54 1/4	34 1/8	41
Underwood Corp.	30 7/8	19 1/8	26 1/2
Union Carbide Corp.	150 1/2	120 1/2	149 1/4
United Shoe Machinery	64 1/4	45 5/8	64 5/8
Varian Associates	53	26 3/4	46 1/4
Wallace & Tiernan	52 7/8	36 1/4	42 3/4
Western Union	52	29 3/4	53 1/2
Westinghouse Air Brake	38 1/2	27 1/2	32 3/4
Westinghouse Electric	110 3/4	70 1/2	107 3/8
Worthington Corp.	84 1/2	59 1/2	64

(1) Not traded - Bid and Asked

These prices and price ranges are given as printed in the Wall Street Journal.

AMERICAN STOCK EXCHANGE

PRICE RANGE 1959 THRU DECEMBER 19, 1959

	High	Low	Price As Of 12/17/59
American Meter	47 1/4	38	44 1/2
Aro Equipment	29 3/4	20 3/4	24 1/4
Barry Controls "B"	26	13 3/4	22
Belock Instruments	22 7/8	10 3/8	17 3/4
Benrus Watch	9	5 1/2	6
Breeze Corp.	9 1/8	6 1/8	7 5/8
Clark Controller	30 3/8	19 5/8	22 [illegible]

Continued on page 50

can save up to 40% on many pressure gauge applications

Analyzed your gauge needs lately—how much gauge performance you're getting, compared to what you need and what you pay for? Perhaps it's time for a closer look at United States Gauge with its line of 50,000 standard pressure gauges, plus specials (and all possible choices in case styles, sizes, materials and pressure ranges). For example, note how you can save up to 40% on premium gauges and still get premium performance with the USG A-Line *(top, right)*. Note, too, how you can get the exact gauge for *any* need and cut waste of under-buying or "over-gauging" . . . from all the gauge lines available at this one source. Then check the USG distributor listed in your Yellow Pages. Or write direct for catalogs and name of your nearest distributor today.

UNITED STATES GAUGE
Division of American Machine & Metals, Inc., Sellersville, Pa.

Find Your Nearest Distributor in The "Yellow Pages"

Paying needless premium prices for reliability? USG A-Line pressure gauges have premium construction, save up to 40% on premium prices. Meet A.S.A. Grade A standards, including 1% accuracy. Extra rugged, they are built to *deliver* longer under severe operating conditions, where you do not require the accuracy of Grade AA gauges, but where reliability and cost-cutting are "musts". Wide choice of Bourdon tubes, case styles and sizes, pressure ranges, and movements. You must see the sturdy design and price to believe the value and performance. Models for general-purpose service, altitude, refrigeration, ammonia and hydraulic applications. *Write for Catalog 305.*

Buying too much gauge for your purpose? Save with volume-priced, precision-built USG Drawn Case Gauges for service where your gauge need calls for A.S.A. Grade B standards, including 2% accuracy. *Write for Catalog 64A.*

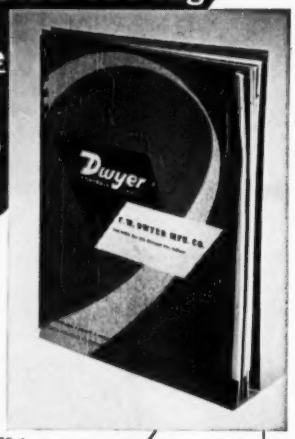
Getting all the accuracy you're paying for? You can't buy more precision than with USG Test Gauges which meet or exceed A.S.A. Grade AA standards, including accuracy as high as 0.2 of 1%. *Write for Catalog 400.*

CIRCLE 49 ON READER-SERVICE CARD

NEW 72-page GAGE and CONTROL Catalog

..tells where to use them..

..WHY and HOW!



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GREEN INSTRUMENT COMPANY, INC.

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CIRCLE 51 ON READER-SERVICE CARD

AMERICAN STOCK EXCHANGE *continued from page 48*

Clarostat Mfg.	17 1/2	4	14 1/2
Clary Corp.	10 7/8	5 3/4	7 5/8
Du Mont Laboratories	9 7/8	6	9
Dynamics Corp. of America	12 3/4	44 5/8	11 5/8
El-Tronics	2 1/4	1	1 3/8
Electronics Corp. of America	16 7/8	7 1/2	9 1/8
Fairchild Camera & Instrument	149 1/4	126	128
General Transistor	45 3/8	29	29 5/8
Globe-Union	29 1/4	20 1/4	27 1/2 Bid 24 1/2 Asked
Hazeltine Corp.	33	23 1/2	32
International Resistance	22 3/4	7	19 5/8
Loral-Electronics	39 7/8	28 5/8	35
National Research	39 1/2	15 3/8	21 1/2
New Haven Clock	5 3/8	1 1/2	2 1/4
Nuclear Corp. of America	4 1/4	1 3/4	2 1/2
Philips Electronics, Inc.	50 1/4	23 1/2	42
Pneumatic Scale	67	32	46 1/8
Servo Corp. of America	43 1/2	14 5/8	24 3/8
Servomechanisms	18 1/4	9	10 5/8
Statham Instruments Inc.	43	23	34 1/2
Victoreen Instrument Co.	19 7/8	6 7/8	12 3/8
Waltham Prec. Instrument Co.	4 3/8	1 1/8	3 1/8

(1) Not Graded- Bid and Asked

These prices and price ranges are given as printed in the Wall Street Journal.

OVER THE COUNTER

	Quotation as of 12/16/59 Bid	Asked
Aerovox Corporation	15 3/4	16 1/2
Argus Corporation	35	35 5/8
Black Sivalls & Bryson Inc.	18	19 1/4
Eitel Mc Cullough	31	32
Electro Instruments	58	63
Electronics Associates	30 1/2	32
Erie Resistor Corporation	9 1/4	9 7/8
Fisher Governor Co.	16 3/4	17 3/4
Foxboro Company	74	79
Giannini Controls	39	41 1/2
Hagan Chemicals & Controls	35 3/4	37 1/2
Industro Transistor	15 1/4	16 1/2
Liquidometer Corp.	11 1/2	12 3/4
W. L. Maxson	13 5/8	14 3/4
Penn Controls	23	23 3/4
Speer Carbon, Inc.	21 1/2	23
Sprague Electric	63	66 1/2
Taylor Instruments	40	44 1/2
Telecomputing Corp.	12	13
Topp Industries	10 1/2	11 1/4
Vitro Corp. of America	12 1/2	13 1/4

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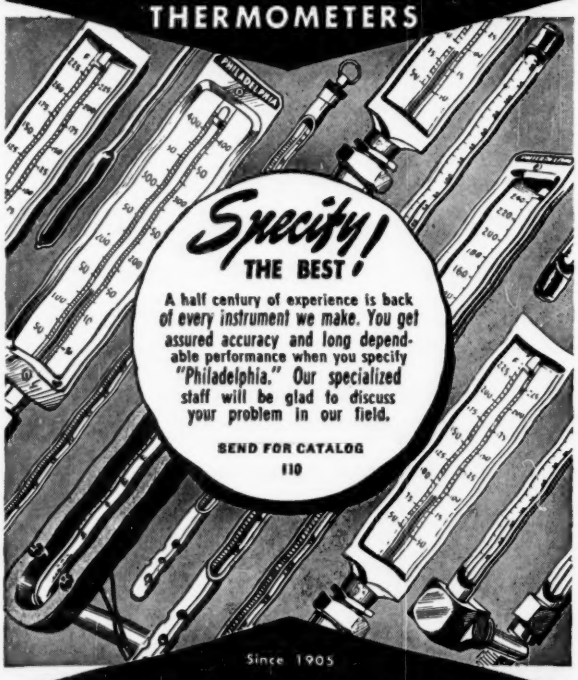
THERMAL CONTROLS AND THERMOMETERS



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Nash Instrument Air Compressors deliver only clean air, free from oil or dust, and without filters

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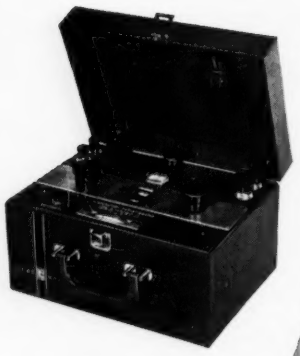
You can dispense with oil filters and dust filters when you install ®Nash® Clean Air Compressors. You can save the cost of maintaining these devices. You can greatly reduce instrument maintenance costs. For the Nash employs no internal lubrication, therefore no troublesome oil is in the delivered air. Moreover, air from a Nash is thoroughly washed and cooled as it passes thru the pump. Dust in the plant atmosphere, even fly ash, is immediately removed.

®Nash® Clean Air Compressors are simple, with only one moving element. No valves, gears, pistons, sliding vanes, or other enemies of long life and constant performance complicate a Nash. No aftercoolers are needed. You will find it profitable to investigate these pumps, now.

No oil filters.
No dust filters.
No internal lubrication to contaminate air handled.
No internal wearing parts.
No valves, pistons, or vanes.
Non-pulsating pressure.
Original performance constant over a long pump life.
Low maintenance cost.

NASH ENGINEERING COMPANY
370 WILSON, SO. NORWALK, CONN.

Make speedier checks of recorders, controllers and base or noble metal thermocouples in industrial plants with the new three-dial 8686 Portable Millivolt Potentiometer. Features such as a central reading window . . . where measured values appear as a row of digits with a scale interpolation . . . simplify calibration of thermocouples and test measurements. The 8686 Potentiometer has: a wide operating range of −10.0 to +100.1 mv and +1010 to +1020 mv for standard cell calibration; and a high accuracy of ±(0.05% of reading +3μv) without reference junction compensation, ±(0.05% of reading + 6 μv) with ref. jct. comp. Write for Data Sheet E-33(1A).



8686 Millivolt Potentiometer

8690 Millivolt Potentiometer

Fast, accurate in-plant checking of thermocouples, recorders and controllers is expedited by the new 8690 Portable Millivolt Potentiometer. Design features such as "In-line Readout", which permit measured values to be read in digits with a scale interpolation, accelerate temperature measurements. The 8690 provides a wide range of −11.0 to +101.0 mv which eliminates input reversals; an accuracy of ±(0.05% of reading + 20 μv) without reference junction compensation, ±(0.05% of reading + 40 μv) with ref. jct. comp. Write for Data Sheet E-33(1B).

4 time-saving instruments from the

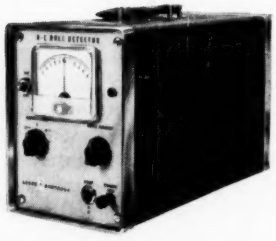
NEW

CONVENIENCE-STYLED L&N LINE . . .

8692 and 8693 Temperature Potentiometers

If you want to make a variety of temperature measurments quickly with one flexible instrument, investigate the new time-saving 8692 Single-Range or 8693 Double-Range Temperature Potentiometers. Available in any of 24 interchangeable temperature and millivolt ranges, these instruments read directly in degrees F or C on a scale 27½" long. Convenience features include: simplified range changes . . . only a screwdriver is needed to change a circuit panel, scale and binding post studs; automatic reference junction compensation . . . reference coil, built into circuit panel, compensates for thermocouple being used; accuracy . . . ±0.2% of range. Write for Data Sheet ND42-33(1A).

Need a fast-operating, high-sensitivity, high-quality null indicator for use in research, testing and production checking? Here's a new 9834 Guarded D-C Null Detector having a short period of less than two seconds for source resistances up to 1000 ohms, increasing to 4 seconds at 100,000 ohms . . . ideal for measurements with guarded or unguarded potentiometers and bridges. Of rugged construction, this portable, line-operated detector provides numerous convenience features which include four degrees of sensitivity, with a basic sensitivity of 0.2 μv/mm (0.3 μv/scale div.), and a noise level of less than ±0.1 μv. Write for Data Sheet ED7(2).



9834 Guarded D-C Null Detector

LEEDS & NORTHRUP
4955 Stenton Ave., Philadelphia 44, Pa.

CIRCLE 53 ON READER-SERVICE CARD

SCIENTIFIC AND PROCESS CONTROL INSTRUMENT INDUSTRIES OUTLOOK FOR 1960 AND REVIEW OF 1959

Summary

Sales of scientific and process control instruments are expected to reach $4.5 billion in 1960, representing about a 15 percent increase over the $3.9 billion estimated for 1959, the Business and Defense Services Administration, U. S. Department of Commerce, has reported. Most of this increase will occur in the process control instrument field because of significant increases in plant and equipment expenditures by the chemical and petroleum refining industries (18 percent) and the ferrous and nonferrous metals industries (56 percent). A larger portion of these capital outlays is expected to be devoted to modernization in 1960 than in previous years, pointing to a higher ratio of instrument sales per dollar of capital investment.

Spending for laboratory facilities in 1960 by Government and private industry is expected to total the same as in 1959. The reduction in military purchases of aircraft in 1960 is expected to be offset in part by increased purchases of jet planes by commercial airlines, plus a rise in the spending by the Department of Defense for missiles, ships and harbor craft, and electronic and communications equipment.

Background

Scientific and process control instruments are used to measure, indicate, record and/or control electrical, chemical, and physical quantities. They operate completely automatically, on the basis of electrical, optical, gyroscopic, and other physical principles such as expansion of gases, elastic deformation, and the like.

Not discussed in this release are machinist's precision tools, such as calipers, micrometers, gauge blocks, and measuring scales; or slide rules, drafting and plotting instruments, templates, and similar items grouped under Standard Industrial Classification 3811—Engineering, Laboratory, and Scientific and Research Instruments and Associated Equipment.

Scientific and process control instruments are divided into about a dozen industry classes. The only feature common to any one of these diverse groups is that its products more or less compete in the same market. This is true because the same function can be performed by a variety of instruments, each of which is markedly different in physical structure, design, and operating characteristics, and requires production facilities which are not inter-changeable with those needed to produce the other types. On the other hand, the same type of instrument may satisfy a variety of functions.

Taken as a whole, the scientific and process control instrument field is a multi-firm, multi-product complex, comprised of over 1,000 establishments producing more than 100,000 different catalogued instrument products. Many of the firms in this field have roots in older industries, having begun the manufacture of instruments because of the rapidly expanding demand after World War II.

Technological developments within the scientific and process control field since the war have been astounding—most of them occurring in a mere decade, in contrast to more than 50 years in other industries. The major portion of instrument sales is of products which were not in existence before World War II. About 50 percent of the instruments on the market today came into being within the past few years.

The manufacture of instruments is an old industry, but a revolutionary transformation has occurred in the status of the industry within the past 10 years. At the same time, great progress has been made by the industry in extending the range, precision, sensitivity, applicability, reliability, and adaptability of its products. The rate at which the frontiers of science are being pushed back is due to the increasingly greater degrees of precision and accuracy available in instruments.

Scientific instruments have been important factors in cost reduction in industrial processes. Many of the high standards of quality and uniformity demanded of products today can only be achieved through the use of automatic process-control instruments.

The instruments discussed in this release have been grouped in the following categories, in terms of the economic sectors that are related to their demand:

1. *Scientific instruments* are used in research and development, meteorology, astronomy, geodesy, and similar scientific pursuits.

2. *Industrial instruments* are used in measuring, recording and/or controlling process variables; or in testing materials, parts, and assemblies being manufactured or following manufacture.

3. *Component instruments* are incorporated into an end product such as an airplane, guided missile, marine vessel, etc., or integrated, together with various adaptive and accessorial devices, into an instrument system that is designed for a specific application such as missile tracking and monitoring systems.

Continued on page 54

EDITORIAL—CONTINUED

Continued from page 53

The above categorization does not distinguish instruments from either a structural or functional point of view. The same type of instrument may be found in the laboratory, manufacturing facility, an airplane, a guided missile, an airport, or a missile station instrument system.

Sales of scientific instruments are not directly related to total expenditures for research and development—only to the outlay for new research and development facilities. On the other hand, overall research and development expenditures can be increased without a single instrument being purchased, by a more intensive utilization of those available.

Table 1 indicates little correlation between total spending on research and development and the building of additional research and development facilities. Also, sales of scientific instruments may decrease during a period in which overall expenditures for research and development are rising. Finally, the costs of conducting research and development may increase while expenditures for the increase of research and development facilities are declining—as occurred during the period 1951-1955.

Government budgetary information provides the only data in which research and development expenditures are broken down according to those defraying the expenses of conducting research and development, and the amount going towards additional facilities. However, Federal research and development spending accounts for the most significant portion of the Nation's total expenditures for research and development. Therefore, the Federal data are important in projecting the overall demand for instruments.

Industrial instrument sales are linked to expenditures for new plant and equipment. However, the aggregate of capital investment by all industries must be broken down before the data may be used in predicting instrument sales, because the ratio of these to capital expenditures varies significantly among industries. This ratio is primarilly influenced by the extent to which the processes of an industry lend themselves to instrumentation from the standpoints of technical feasibility and economy of operation.

The ratio of instrument sales to total industrial capital expenditures during the period 1947-57 was as follows:

Industry group	Percent of instrument sales	Percent of total capital expenditures
Chemical	16.6	4.0
Petroleum	12.5	9.5
Public utilities	13.0	15.1
All other manufacturing	30.4	24.3
All other non-manufacturing	3.8	47.1
Total	76.3	100.0

Another important factor to consider in using data on expenditures for new plant and equipment, is the distribution of the expenditures between spending for plant and purchases of new equipment. The greater the proportion going towards modernization of existing facilities rather than plant expansion, the larger is the relative share of total capital outlays that are devoted to instrumentation.

The sales of component instruments are related to the purchases of the end products using this class of instruments, such as airplanes, missiles, ships, etc. Since the data on capital expenditures by the transportation industries reflect mainly spending for transportation equipment, these data are used in connection with forecasting sales of component instruments. Similarly, capital outlays by the commercial sector of the economy are primarily devoted to the construction of buildings, which affects the sales of instruments used for regulating heating, ventilating and air conditioning systems. Therefore, the expenditures for new plant and equipment by all other non-manufacturing industries are geared to component instrument sales,

However, the most significant portion of the sales of component instruments is attributed to spending by the Federal Government, especially the Department of Defense and the Federal Aviation Agency. The latter's budget includes outlays for commercial air traffic aids such as instrumental landing systems, air navigation facilities, etc.

The Department of Defense (DOD) is the largest single purchaser of end products containing instruments as components. In addition to the military counterparts of civilian air traffice aids, the DOD budget provides for aircraft, guided missiles, installations for launching and monitoring the missiles, target tracking devices, weapons control systems, and the like.

Trends in 1959

Scientific instruments. According to the National Science Foundation, the Federal Govenment's obligations for additions to research and development facilities will total $539 million during fiscal 1959. This represents an increase of $183 million over fiscal 1958.

According to trade publications, private industry will spend an estimated $160 million during 1959 for new laboratory installations. This is about 30 percent more than was spent on research and development facilities during 1958 by the private sectors of the economy.

These figures substantiate the estimate of an approximate 20 percent increase in the 1959 sales of scientific instruments.

Industrial instruments. Industrial instrument sales are expected to increase in 1959 between 15 percent and 20 percent over 1958.

Component instruments. Budgetary data for commercial traffic aids reflect an increase of $36.5 million during fiscal year 1959 over 1958. Comparisons between 1958 and 1959 Department of Defense budgetary data show the following for the latter year: aircraft—$7,658 million, down by $790 million; missiles—$3,494, an increase of $757 million; ships and harbor craft—$1,537, up by $381 million; electronics and communications—$912 million, a rise of $35 million.

Private capital outlays by the transportation and communications industries for 1959 are estimated by $5,847 millions, as against $4,970 millions spent in

TABLE 1—FEDERAL EXPENDITURES FOR RESEARCH AND DEVELOPMENT, FISCAL YEARS 1948-58. (MILLIONS OF DOLLARS)

Fiscal Year	Conduct of research and development	Increase of research and development facilities	Total	Percent of total used for increase of research and development facilities
1948	785	91	876	10.4
1949	954	167	1,121	14.9
1950	1,042	202	1,244	16.2
1951	1,522	330	1,852	17.8
1952	1,910	307	2,217	13.8
1953	1,920	248	2,168	11.4
1954	1,999	227	2,226	10.2
1955	2,045	207	2,252	9.2
1956	2,419	273	2,692	10.1
1957*	2,830	527	3,357	15.7
1958*	3,020	356	3,376	10.5

*Estimated

Source: Federal Funds for Science, National Science Foundation, Volumes III and IV.

1958. Capital outlays by the commercial sectors are expected to reach $7,886 million in 1959, as against an expenditure of $7,041 in 1958.

Component instruments sales will likely increase 20-25 percent in 1959 over 1958.

Total Instrument Sales—1959

Sales of scientific and process control instruments are expected to be approximately $3,900 million in 1959, representing about a 20 percent increase over the estimated 1958 sales of $3,251 million.

The 1960 Outlook

Scientific instruments. The 1960 Federal budget provides for an outlay of $447 million for additional research and development facilities, which is $92 million less than the amount budgeted for 1959. However, private industry is expected to increase its spending for laboratory facilities by at least $100 million.

Industrial instruments. Capital expenditures for 1960 are expected to show a marked increase over those in 1959. Part of the increse is due to the fact that the portion of the initial 1959 estimate for investment is in new plant and equipment, which was retarded on account of the steel and copper strikes, will spill over into 1960. Expected 1960 increases by selected industry groups are as follows: chemical and petroleum refining —13 percent; ferrous and nonferrous metals—56 percent; metalworking—16 percent; other manufacturing —8 percent; electric and gas utilities—3 percent. A decline of 5 percent in capital expenditures by the petroleum production and mining industries is expected in 1960.

Component instruments. The Department of Defense 1960 budget provides for $1,069 million less for airplanes. This is offset by increases in the following categories: missiles—$428 million; ships and harbor craft—$106 million; electronics and communications —$145 million. A major portion of the overall decline of $390 million in these four DOD budget categories is expected to be balanced by the Federal Aviation Agency's spending for commercial airport facilities. Other plus factors are an increase of 12 percent in the 1960 capital spending by the transportation industries over the 1959 capital outlays, and a rise of 9 percent by the commercial sectors of the economy.

Total Instrument Sales—1960

On the whole, any reduced demand for scientific and component instruments in 1960 will be largely counteracted by a sharp rise in industrial instrument sales. It is expected that the 1960 sales of scientific and process control instruments should attain a figure of approximately $4,500 million, an increase of about 15 percent over 1959.

Dear D. R.*:

The report above by the BDSA is a fitting new-year editorial, the start of the "soaring sixties." For details on the actual R&D budget mentioned in this report, see TRENDS (page 19).

We are always a bit amused at predictions, and predict ourselves that the actual market in 1960 will exceed (or not reach) the estimates by considerable amounts, barring plagues, earthquakes and other acts of God, and wars, depressions and other acts of man.

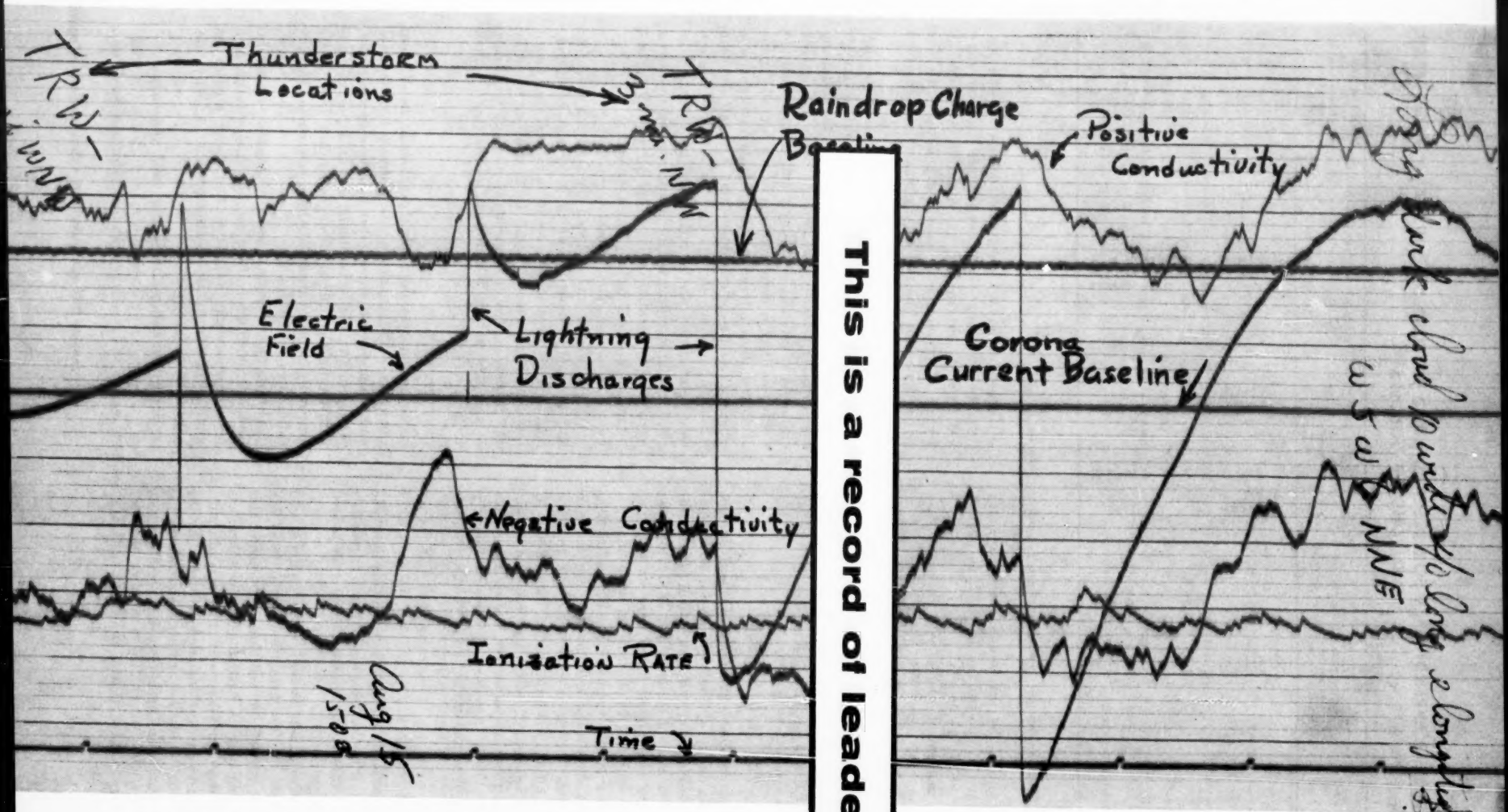
This month's cover was designed, as usual, by the great Ray Smith, whom we humbly nominate as the artist of the year. What appears to be a line drawing on the cover was done photographically by Vincent Chapman of Pittsburgh. In this process a film negative and a film positive are sandwiched in perfect registry, placed on a revolving turntable, and an exposure made with the light source at 45 degrees to the film. There are many subtle variables which can make startling differences in the result.

This month we begin a series of articles on temperature instrumentation. Next month: A disclosure of a new flowmetering technique, and more articles on motion instrumentation—displacement, velocity, acceleration and noise.

Hope this finds you (reading) well and happy.

Milt and the Editors

*Dear Reader



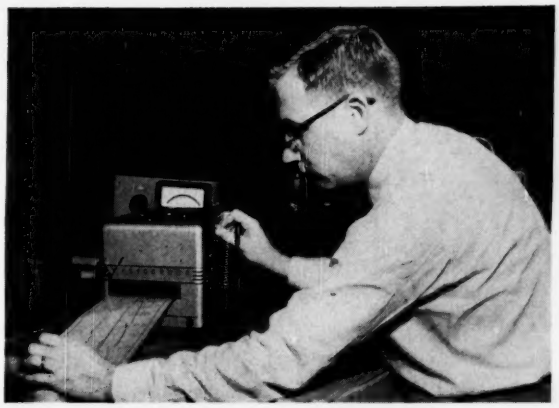
Honeywell 906A Visicorder record, actual size. Note longitudinal grid lines

This is a record of leadership

The U.S. Weather Bureau used a Honeywell Model 906B Visicorder Oscillograph to record directly this diary of a thunderstorm as it passed near the observation station on Mt. Washburn in Yellowstone National Park.

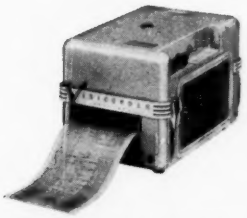
As the storm passed, the Visicorder measured and recorded 1) positive and negative electrical conductivity of the air, 2) the rate of ionization of air due to airborne radio-active particles and extra-terrestrial radiation, 3) the size and charge of individual raindrops, 4) the corona discharge current from an insulated tree and from a 4′x 6′ grass plot to determine current flow from the earth's surface to charge centers in the clouds, 5) times of camera exposure photographing cloud droplet size and electrical charge, 6) atmosphere potential gradient, and 7) time.

The Visicorder made this and many other records on Mt. Washburn without the use of power amplifiers. This feature, plus the extreme portability of the Visicorder, made it the ideal oscillograph for use in these studies.

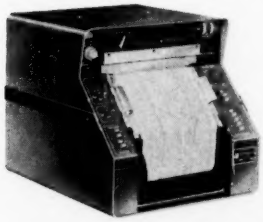


Byron Phillips, U. S. Weather Bureau Scientist, monitors thunderstorm data as it is recorded by the Honeywell Model 906 Visicorder.

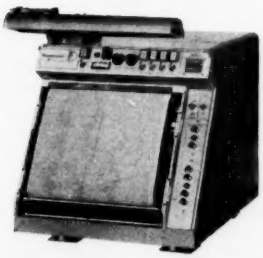
in weather research



Recent Models of the **906 Visicorder** incorporate time lines and grid lines and record up to 14 simultaneous channels of data.



The NEW Model **1108 Visicorder** with many automatic features and the convenience of push-button controls, is ideal for intermediate uses requiring up to 24 channels of data.



The Model **1012 Visicorder** is the most versatile and convenient oscillograph ever devised for recording as many as 36 channels of data.

The Honeywell Visicorder is the pioneer, completely proven, and unquestioned leader in the field of high-frequency, high-sensitivity, direct-recording ultra-violet oscillography. Here are some of the reasons why Visicorders provide the most accurate analog recordings available: constant flat response and sensitivity of galvanometers; grid-lines simultaneously recorded with traces to guarantee exact reference regardless of possible paper shift or shrinkage; flash-tube timing system for greater accuracy of time lines; superior optics for maximum linearity of traces.

No matter what field you are in . . . research, development, computing, rocketry, product design, control, nucleonics . . . the high-frequency (DC to 5000 cps) Visicorder Oscillograph will save you time and money in data acquisition.

Call your nearest Minneapolis-Honeywell Industrial Sales Office for a demonstration.

Reference Data: write for Bulletins 1108, 1012 and HC-906B

Minneapolis-Honeywell Regulator Co.
Industrial Products Group, Heiland Division
5200 E. Evans Avenue, Denver 22, Colorado

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Industrial Products Group

FROM HONEYWELL.. A DIAMOND JUBILEE PARADE OF PRODUCTS

CIRCLE 54 ON READER-SERVICE CARD

HIGH TEMPERATURE MEASUREMENT

Instruments for measurement of high temperatures are often misunderstood and frequently misapplied. An understanding of the four types of devices commonly used for high-temperature measurement—thermocouples, total radiation, brightness (optical) pyrometer and two-color pyrometer—helps the user select the best one for his problem.

VINCENT G. SHAW
Shaw Instrument Corporation

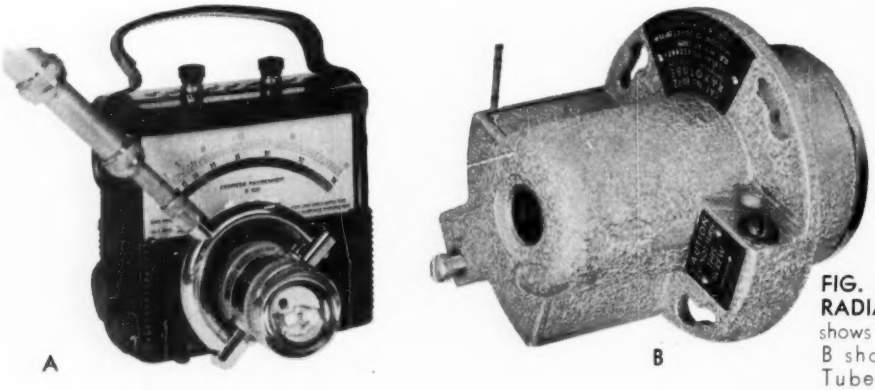
THE FOUR general methods of high-temperature measurement include (1) thermocouples, (2) total radiation devices, (3) brightness or optical pyrometers, (4) two-color pyrometers. The advantages and disadvantage of each of these methods are as follows (Table 1):

Thermocouples

Thermocouples are popular temperature-measuring devices and their advantages and limitations are better understood than those of other devices.

Advantages

1. Thermocouples made of known metals can be used as temperature standards.
2. The thermocouple is an inherently simple device.
3. The thermocouple is often heated by conduction as well as radiation, making it ideal for measuring air or gas temperatures or any medium not radiating enough energy to be measured by other devices.
4. Thermocouples are relatively inexpensive.



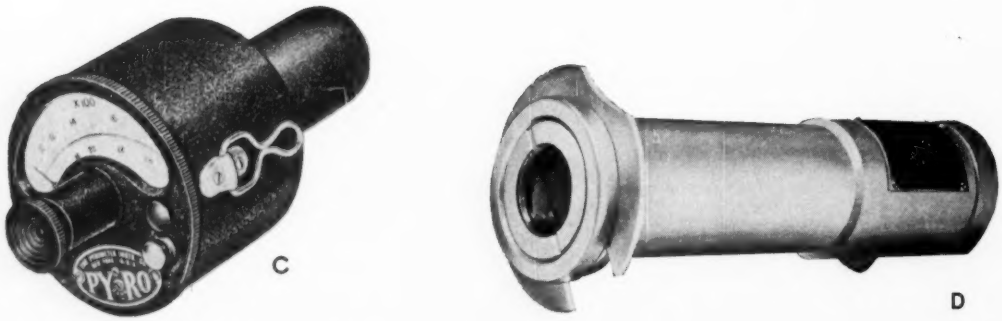


FIG. 1. TYPICAL TOTAL-RADIATION pyrometers. A shows the Land pyrometer; B shows the L&N Ray-O-Tube; C shows the Pyro Optical; D shows the Honeywell Radiamatic.

5. Wide temperature ranges can be measured with a single thermocouple.

6. Thermocouples can be connected readily to many types of indicating and controlling devices.

Disadvantages

1. Thermocouples are subject to aging and poisoning of the hot junction. This is particularly true of couples that are operating near the melting point of the couple metals. This can lead to large errors.

2. The temperature of the junction can vary considerably from the temperature being measured. This is especially true for surface-temperature measurements, or those applications where heat conduction away from the couple junction by the wires is appreciable.

3. The upper temperature is somewhat limited with existing couple materials.

4. Electrical connections must be made to the thermocouples, which means they are not well suited for applications involving moving objects.

5. Auxiliary equipment is needed to measure the thermocouple EMF.

6. The thermal mass of the couple may be large enough to cause response speed problems.

Total Radiation Devices

Total-radiation devices (Fig. 1) measure the temperature of an object by measuring the radiant energy being emitted by the object. Most of this energy is emitted in the infrared region, even for objects as hot as 3000°C. For this reason most total-radiation devices employ thermopiles (a group of thermocouples), although other types of infrared detectors are becoming used more frequently.

Unfortunately, for many purposes the radiant energy emitted by a hot object depends on factors other than its temperature. The radiating ability of an object is called its *emissivity* and, in general, is related to its reflecting ability. A poor radiator (one with low emissivity) is a good reflector. The *total emissivity* of an object is influenced by several factors, including material, shape, and surface conditions. (In this discussion the term "emissivity" will refer to the total emissivity, the over-all radiating ability of an object.)

Where the emissivity is known and remains constant, accurate temperature determinations can be made by a total-radiation device. One advantage of this type of device is its almost unlimited upper temperature. However, calibration for high temperatures is a problem.

The ideal case of fixed and known emissivity is not encountered often in practice. A typical example of varying emissivity is a molten-metal stream. The emissivity is not only affected by the metal but also by the size and shape of the stream. The problem is further complicated by smoke and fumes which are often encountered under such conditions. The emissivity problems associated

TABLE 1—CHARACTERISTICS OF HIGH-TEMPERATURE INSTRUMENTS

	THERMOCOUPLES	TOTAL RADIATION	BRIGHTNESS	TWO-COLOR
Emissivity Effect	None—but requires contact	Very large (less in Land)	Large	None to slight
Sensitivity	Very good	Fair to good	Fair	Good
Lower Limit	−273°C	Variable*	1400°F	1400°F
Upper Limit	3200°F (Pt/Pt-Rh)	Variable**	Variable**	6500°F
Stability	Good at low temp. Poor at high temp.	Fair	Very good	Good
Aging Effect	Severe at upper limits	Moderate	Slight	Slight
Calibration Required for a Particular Application	Usually no	Yes	Yes	No
Can be used with Recorder or Controller	Yes	Yes	No	Yes
Requires Operator	No	No	Yes	No
Relative Cost	Low	Moderate	Moderate	High
Auxiliary Equipment	Voltage measuring device	Voltage measuring device	None	None
Speed of Response	Moderate	Moderate for thermocouple types	Slow	Fast

*Usually 1200°F

**Depends on calibration source

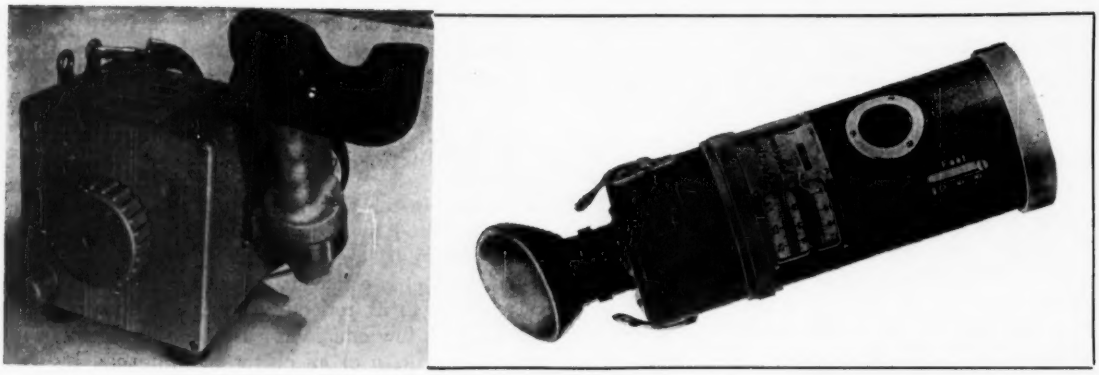


FIG. 2. TYPICAL BRIGHTNESS (OPTICAL) pyrometers. A shows L&N unit; B shows Pyro pyrometer.

with total-radiation devices restrict their use, but there are applications where a total-radiation device is the most practical means of measuring temperature.

Advantages of the Total Radiation Device

1. Construction is relatively simple and rugged.
2. Cost is moderate.
3. Under ideal conditions they can be used to measure very high temperatures.
4. They can withstand fairly high ambient temperatures.
5. EMF output is high.

Disadvantages of the Total Radiation Device

1. Temperature indication is affected by emissivity changes and other non-temperature factors (smoke, haze, dirty sight glass, etc.) which affect the radiation reaching the device.
2. An EMF-measuring device is required.
3. The output of the total-radiation devices is nonlinear with temperature, complicating the measurement.

Brightness Pyrometers

Brightness or optical pyrometers (Fig. 2) measure the temperature of an object by measuring the energy radiated at a particular wavelength, or over a narrow band of wavelengths. Most optical pyrometers measure the energy at wavelengths corresponding to a dark red.

Actual measurement of the radiant energy is made by comparing the apparent brightness of the hot object with the known brightness of a calibrated filament. Here again, the reading is related to the emissivity of the hot object, although brightness is somewhat less affected by emissivity than is total radiation because the wave band of energy used by the brightness pyrometer is much less than that used in the total-radiation device.

Brightness pyrometers have long been popular, and their general ruggedness, portability and versatility will insure their continued use.

Advantages of the Brightness Pyrometer

1. Brightness pyrometers are relatively simple and rugged.
2. They are self-contained (battery operated).
3. Range is wide.
4. Accuracy can be good.

Disadvantages of the Brightness Pyrometer

1. Human operator is required.
2. For accuracy the emissivity of the object must be known. In practice this is seldom the case. (Furnace interiors and special targets of known emissivity are among the few exceptions.)
3. No electrical output is available, precluding its use in recording or controlling applications.

Two-Color Pyrometer

The two-color pyrometer makes *two* brightness temperature measurements, using two different wave bands of energy. As the emissivity of the object being measured affects both measurements in approximately the same manner, the ratio of the two measurements is relatively unaffected by the emissivity of the object. The emissivity need not be known and, perhaps of greater importance, can vary without affecting true temperature readings.

The Shawmeter (Fig. 3) is a commercially-available two-color pyrometer. Automatic operation makes it free from operator errors and the electrical output is suitable for recording or control purposes. Brightness temperature measurements are made rapidly so that fluctuating emissivities or

FIG. 3. TWO-COLOR pyrometer, or Shawmeter.

changes in the radiation path do not affect the temperature readings.

Advantages of the Two-Color Pyrometer

1. Operation is automatic.
2. It is relatively free from emissivity effects and their necessary corrections.
3. It is relatively free from effects caused by smoke, fumes, dirt films, etc.
4. Sensitivity to radiant energy is high; only a small target area is required.
5. Response speed is high.
6. Direct-reading scale is linear.
7. Range can be extended readily.
8. Electrical output is suitable for recording or controlling.

Disadvantages of the Two-Color Pyrometer

1. Instrument is relatively complex.
2. Inherent instability, although small, is greater than that of a thermocouple.
4. Reading can be affected by bright light reflecting from the surface of the object when the object has low emissivity (high reflection) and its temperature is relatively low.
5. Long warm-up time (½ hour) before instrument can be used.

Appropriate Applications

Several typical temperature measuring problems can be cited to indicate the temperature measuring device best suited for each.

1. Small Furnaces

A. Thermocouples are good for measurement and control if the maximum temperature is not too high for their use.

B. Total-radiation devices are good if temperature is high, or if the furnace atmosphere makes thermocouple protection difficult.

C. Brightness pyrometers are good for occasional temperature checks, particularly if the temperature is high, or if no other temperature indicators are provided.

D. A two-color pyrometer is too expensive unless also used for other more difficult measuring problems. However, where the furnace temperature is too high for thermocouples, and difficulty is encountered in maintaining a constant-emissivity target for a total-radiation device, a two-color pyrometer is indicated.

2. Molten-Metal

A. For close control, a total-radiation device with a radiant-energy pipe appears to be the most satisfactory method.

B. Many problems of this general type can be solved by using immersion thermocouples.

C. Some molten-metal temperature problems do not lend themselves to solution by total-radiation devices or thermocouples. In these instances the two-color pyrometer may offer a satisfactory solution.

3. Moving Hot Objects

A. Thermocouples are sometimes used, but they are often inconvenient and can be hazardous.

B. Changing emissivity, smoke, haze, etc., make the use of total-radiation devices or brightness pyrometers impractical if not impossible.

C. The two-color pyrometer has provided successful in measuring temperature of moving hot objects, in or out of a furnace.

4. Molten-Metal Streams

A. Use of thermocouples is difficult.

B. Brightness pyrometers and total-radiation devices are of little or no value in this type of measurement.

C. The two-color pyrometer can be used successfully for this difficult problem.

5. Objects of Unknown or Changing Emissivity

A. Thermocouples can be used if contact can be made with object.

B. Brightness or total-radiation pyrometers are unsuitable.

C. The two-color pyrometer is relatively independent of emissivity effects and often can be used in this type of application.

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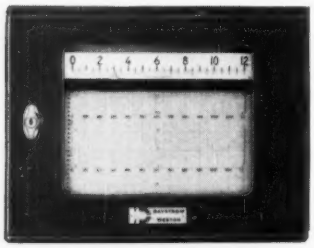
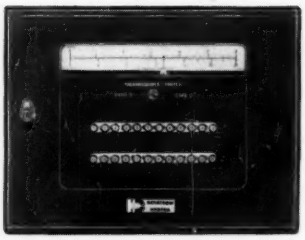


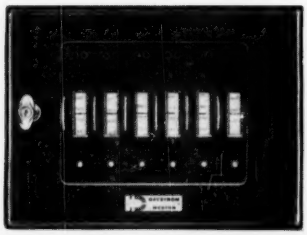
Single- or multi-point

INDICATING



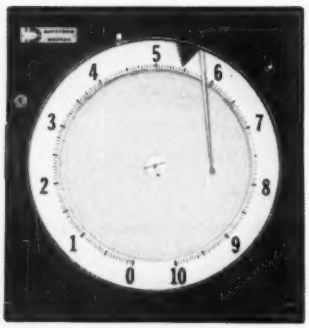
Single- or multi-point

CONTROLLING



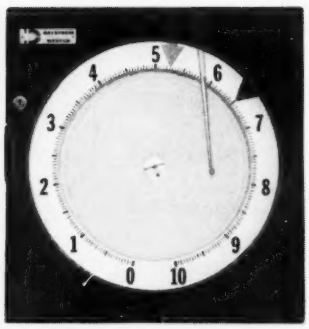
Multi-point (non-indicating)—on-off

RECORDING



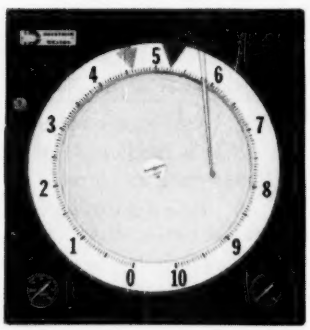
Single-point

CONTROLLING



Single-point—electric

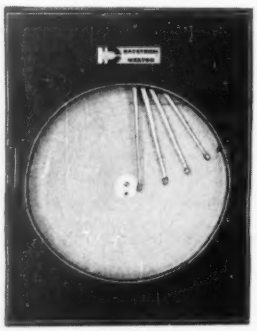
CONTROLLING



Single-point—pneumatic

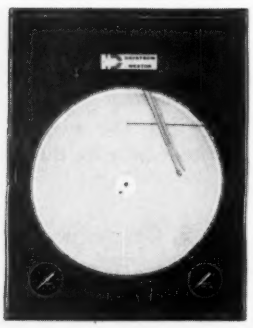
MECHANICAL INSTRUMENTS

RECORDING



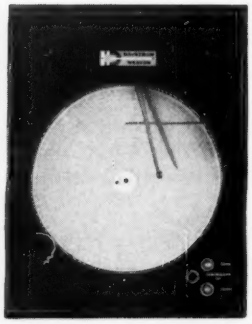
One to four pens

CONTROLLING



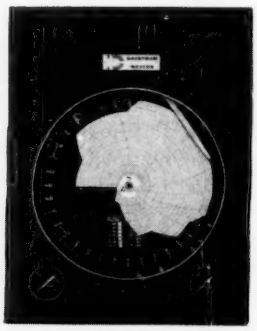
Pneumatic

CONTROLLING



Electric proportional

PROGRAMMING



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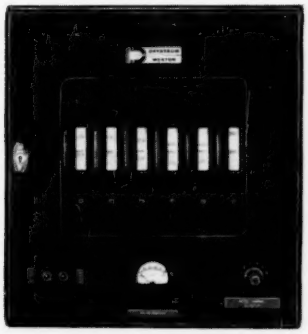
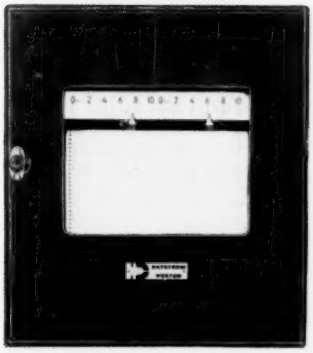


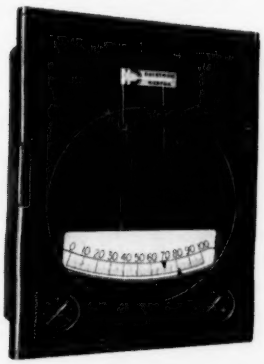
Multi-point (non-indicating)—proportional

RECORDING



Two-pen, two-zone

CONTROLLING



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The Ratio Pyrometer

Basic defect of radiation or optical pyrometers is dependence on emissivity of radiator. The ratio pyrometer, which is free of emissivity errors under certain conditions, represents an important step upward in pyrometry.

DAVID L. BURK
Allegheny Ludlum Steel Corp.

A RATIO or two-color pyrometer uses the radiation emitted by an incandescent object to indicate the object's temperature.

The theoretical mathematical expression for the radiant energy (watts/cm^2) available for emission by an incandescent body is given by Planck's Law:

$$J_\lambda = C_1 \lambda^{-5}/(e^{-C_2/\lambda T}-1) \qquad (1)$$

where J is amount of energy radiated per unit area, per second, at wavelength λ, and T is the radiator's absolute temperature. A surface which actually radiates this amount of energy is a perfect radiator and also a perfect absorber of radiation, it is referred to as a *black body*.

Planck's Law reduces within 1% to a simpler expression known as Wien's equation, for radiation in the visible portion of the spectrum and temperatures below 7000°F:

$$J_\lambda \cong C_1 \lambda^{-5} e^{-C_2/\lambda T} \qquad (2)$$

As this is the region of the spectrum and the temperature range in which we are interested, Wien's expression will be used hereafter.

It is an experimental fact that most surfaces are *not* perfect radiators. Intensity of the radiation passing through the surface and thus emitted is less than that given by the theoretical expression because of internal reflection at the surface. It is not possible to take account of this surface property in a theoretical discussion of emitted radiation because of the diverse conditions encountered in practice. However, the formal expression of Wien's equation can be retained and these surface properties accounted for by introducing an empirical parameter called *emissivity* (ϵ_λ):

$$U_\lambda = \epsilon_\lambda C_1 \lambda^{-5} e^{-C_2/\lambda T} \qquad (3)$$

U_λ is the amount of energy actually radiated by a surface whose emissivity is ϵ_λ; ϵ_λ is dimensionless and assumes values between 0 and 1. Emissivity usually is a function of wavelength and temperature. It is the ratio of the amount of energy emitted by the surface in question at a given wavelength to that emitted by a black body at the same temperature.

The *ratio* of the energy emitted by a surface at two different given wavelengths is:

$$R = U_{\lambda 1}/U_{\lambda 2} = \frac{\epsilon_{\lambda 1} C_1 \lambda_1^{-5} e^{-C_2/\lambda_1 T}}{\epsilon_{\lambda 2} C_1 \lambda_2^{-5} e^{-C_2/\lambda_2 T}} \qquad (4)$$

Expression (4) embodies the principle of operation of the ratio, or two-color, pyrometer. *If the emissivities at the two wavelengths are equal,* the emissivity factor drops out of the equation. Thus the ratio of emitted energy can indicate actual temperature even though both emissivities are as high as 0.9 or as low as 0.09.

The optical pyrometer depends on emissivity at a selected wavelength; in contrast, the two-color pyrometer depends on the *emissivity-verusus-wavelength characteristic* of the surface. The slope of this characteristic may be positive or negative. If positive, the observed ratio temperature will be lower than the actual temperature; if negative, the observed ratio temperature will be higher than the actual temperature. Thus a ratio pyrometer is free from emissivity errors if the emissivity is independent of wavelength. Fortunately the emissivity of most surfaces varies only slowly with wavelength; therefore the ratio of emissivities remains close to 1. The ratio pyrometer exploits this slow variance of emissivity with wavelength.

Shaw Ratio Pyrometer

The Shawmeter (Fig. 1) uses one photomultiplier to detect the intensity at two wavelengths. (Use of one tube eliminates the need for matching two tubes). A red plastic disc containing a narrow blue

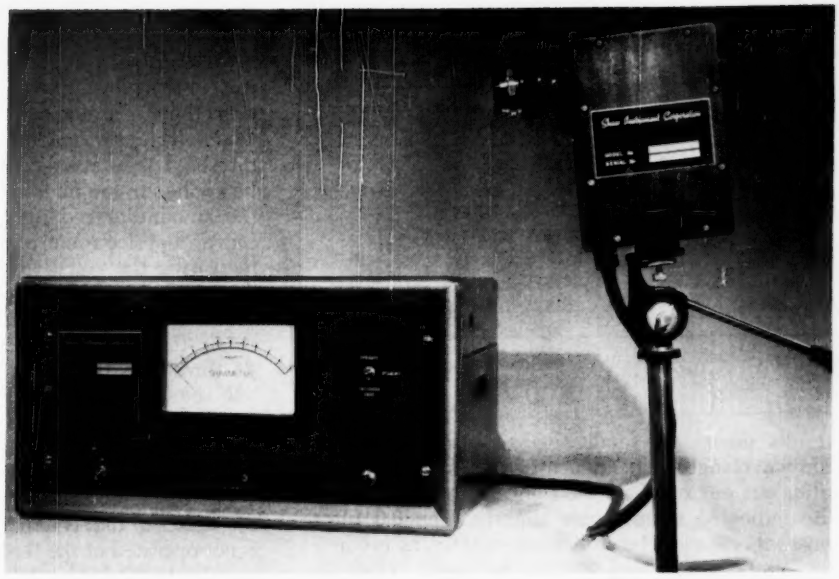

FIG. 1. THE SHAW ratio pyrometer.

segment rotates in front of the multiplier tube, admitting red and blue light alternately. An electronic regulator varies photomultiplier voltage while "seeing red" so that the (red) output signal is maintained essentially constant—the higher the incident (red) intensity, the lower the voltage on the tube. Thus, the voltage on the photomultiplier tube detecting the blue light depends on, and is inversely proportional to, the amount of red light received. The meter receives the photomultiplier output signal only during this much shorter blue part of the cycle. Meter indication is now proportional to the ratio of the blue to the red light because the gain of the photomultiplier has been established during the red portion of the cycle and its output taken during the blue portion.

Evaluating the Shawmeter

It is evident from expression (4) that, if an instrument is looking at a black body, a *neutral-density filter* inserted in the light path does not affect the meter indication. Such a filter changes the black body to an apparent grey body by reducing transmissivity equally at all wavelengths. Some Bausch and Lomb neutral-density filters were obtained to explore this feature.

Transmission data for these filters revealed that the transmission-vs-wavelength characteristic is fairly flat, but a small slope does exist. One filter with an optical density equal to 0.3 had a positive slope in its transmission characteristic, while a 0.6 filter had a negative slope and a 1.2 filter had a positive slope. However, the filters approximate neutral density much closer than anything else available. Inserting the positive-slope 0.3 filter should lower the indicated temperature; inserting the 0.6 filter should raise it; the 1.2 should drop it considerably because of a stronger positive slope.

Black-body conditions were approximated by stacking two 4½″ x 2½″ x 9″ K-30 straight bricks with centers hollowed out, providing a cavity 3½″ x 3½″ x 8″. A 1″ hole was cut through to the cavity and the stack placed in the center of a Harrop furnace which has four globars on each side. The radiation emitted by this aperture is believed to be close to black-body radiation.

This is supported by the following observations: Optical pyrometer readings using a new Leeds & Northrup instrument have been compared with the readings obtained from a Pt-10% Rh/Pt thermocouple situated at the center of the cavity. These two devices exhibit only a 10° ± 5°F systematic error over a temperature range from 1400° to 2800°F. The temperatures obtained with the optical pyrometer are higher than those recorded by the thermocouple. This is considered good agreement between two independent means of detecting the cavity's temperature, especially over such a large temperature range. The 1″ aperture is the radiant energy source used for the test described hereafter.

Table 1 gives the results of interposing the various neutral-density filters and combinations between the black body and the Shawmeter (Type SML, with a range from 1800° to 2800°F). The

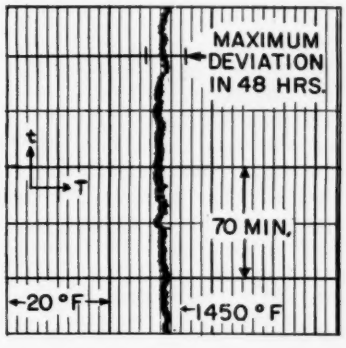

FIG. 2. TYPICAL run on black body at 1450°F.

TABLE 1—EFFECT OF NEUTRAL DENSITY FILTERS ON SHAWMETER

Transmissivity (%)	Filter Density	SML Reading (°F)	Change from Original Reading (°F)	Calculated Change in Reading (°F)
100	0	2765	0	0
50	0.3	2740	−25	−21
25	0.6	2780	+15	+35
12.5	0.3+0.6	2756	−9	
6.25	1.2	2617	−148	−85
3.13	1.2+0.3	2595	−170	
1.56	1.2+0.6	2625	−140	

results shown are qualitatively as predicted from the wavelength dependence of the filters. The 0.3 filter cut out one-half the light, but only dropped the indicated temperature slightly. The 0.6 filter raises the Shawmeter indication slightly, as predicted, while cutting out 75% of the light. The two used together cut out 87% of the light, and their separate effects on the Shawmeter reading tend to cancel out. This is striking confirmation that this instrument's indicated temperature is independent of the intensity of the incident radiation—as predicted for a ratio pyrometer.

A calculation can be made to show how much these neutral-density filters shift a theoretical ratio pyrometer. This has been included in the last column of Table 1. The three calculated temperature shifts support the measured shifts; one is almost identical, one is smaller and the other is larger. In view of this, it can be concluded that the instrument responds, as far as emissivity is concerned, as a theoretical ratio pyrometer.

The Shawmeter's response does depart from that expected theoretically in one important respect—the meter indication is linear with temperature. This enhances the usefulness of the instrument because it provides an output which is proportional to the temperature, thus enabling any linear strip chart to record the indicated temperature directly.

Stability

The next part of the test investigated the instrument's reliability and precision. The black body described can maintain a constant temperature for long periods of time. The thermocouple has been observed to remain constant to within a few degrees over periods up to 48 hours.

If the Shawmeter observes this constant-temperature source, any wander of the record trace will be due to the instrument. Fig. 2 is a reproduction of a recorder trace taken with the SMW, low-temperature-range Shawmeter (range from 1400°F to 1900°F). The maximum excursions from an average line during a 48-hour period were ±3.5°F. Such an excursion (3.5°F) indicates a stability of ±0.7% of the range (500°F). The higher temperature (SML) Shawmeter has been observed to have a stability within ±0.4% of its range (1000°F).

Threshold

Previously it was shown that the meter indication was independent of the incident intensity. However, there is an incident radiation threshold below which the instrument will not operate. This threshold is established by the voltage which can be applied to the photomultiplier tube safely. When the amount of red light decreases, whatever the cause, the electronic regulator counteracts this by increasing the voltage on the multiplier. Near the threshold this tube is operating considerably over its rated voltage. When the incident radiation is below threshold, the meter is pinned down scale. At threshold, the meter indication is sensitive to line-voltage fluctuations. Above threshold the instrument is insensitive to line-voltage fluctuations—input voltage can be varied from 90 to 130 volts with negligible effect on meter indication.

The threshold is most apparent at the low end of the scale. All that is important is that the instrument is not operated at the threshold. In practice this can be determined simply by decreasing the lens aperture; if the instrument is close to the threshold, closing the lens one or two diaphragm stops will pin the meter down scale.

Response

Response speed is limited basically by the 60-rps speed of the rotating plastic two-color filter. If the regulator requires three cycles to fix the voltage across the multiplier tube, the most rapid response possible would be about 1/20 second. However, the actual speed of response appears limited by fatigue characteristics of the photomultiplier. After interrupting the light beam for 30 seconds, the high-temperature unit gives a small up-scale transient, even at the upper end of the scale where the incident intensity is high. It returns to the original reading within about ½ second. It is difficult to say whether this overshoot is due to fatigue or overshoot in the electronic regulator. The low-temperature (SMW) unit, which uses a different multiplier, responds much slower after such an interruption; about 3 seconds are required for this instrument's output to return to within 10° of the original reading, 30 seconds to reach equilibrium. The manufacturer says that this behavior is a property of the individual multiplier tube.

Calibration

The calibration of the instrument was checked using the optical pyrometer readings as the cavity's temperature. The linearity of the calibration of both instruments is within 10°F. The calibrations were found to be reproducible to within 10°F during cycling over the temperature scale, as well as during day-to-day operation. The actual calibration of the 1400°-1900°F unit was reproduced to within 10°F. The calibration at the low end of the 1800°-2800°F unit was reproduced within 10°F, while the upper end was found to be low by about 50°F.

This could mean that the furnace used by the

manufacturer to calibrate the instrument at the highest temperature had an effective emissivity somewhat less than one. A different furnace was used for the low-temperature calibrations by the manufacturer.

Warm Up

When the Shawmeter is first turned on and exposed to the black-body radiation, a long warm-up time is required before the meter indication reaches calibration value. In Fig. 3 the instrument initially reads 150° high and takes 35 minutes to come within 10° of the final value, which is reached in about an hour. This long warm-up time is due to the fact that the spectral sensitivity of the photomultiplier tube is temperature dependent.

In order to prevent variation of the meter indication due to fluctuations in the ambient temperature, the photomultiplier tube is housed in a heavy copper shield which is held at about 120°F. Heating the components of the photomultiplier inside the vacuum envelope takes time. Once the interior of the tube is at thermal equilibrium the output is steady.

Mill Setup

The Shawmeter is easy to use under mill or laboratory conditions. The sensing head can be connected to the power-supply-amplifier unit by several feet of cable. The head can be aligned visually through the eyepiece. Temperature can be observed from a distance because the field need not be entirely filled with radiation. An adjustable linear output of the order of 100 mv is provided and can be recorded directly.

As with any radiation device, the instrument is activated by the radiation visible in its field. If the object viewed is not at a uniform temperature, the resulting indication will be some weighted average determined by the relative areas and temperatures. Also, radiation reflected from some other source can affect indicated temperature.

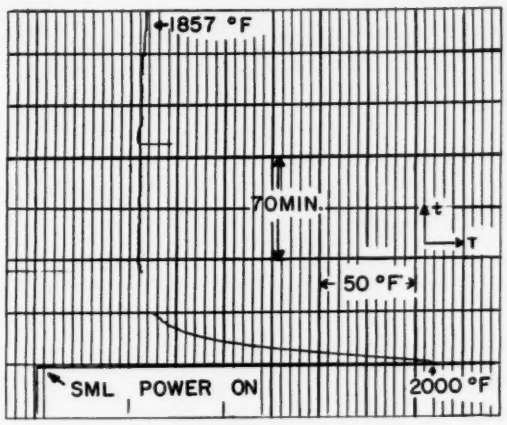

FIG. 3. WARM-UP time of pyrometer.

Conclusions

It can be concluded that the Shawmeter is capable of doing its job. The shortcomings, including relatively high threshold at low temperatures, long warm-up time and phototube fatigue, either have small enough magnitude or otherwise do not restrict the usefulness of the instrument as long as one is aware of their existence.

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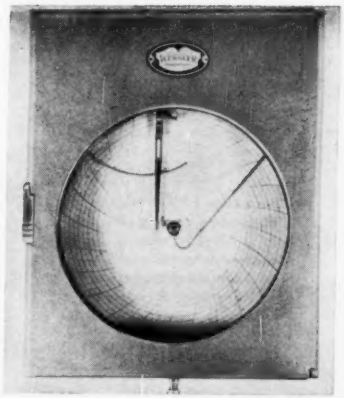

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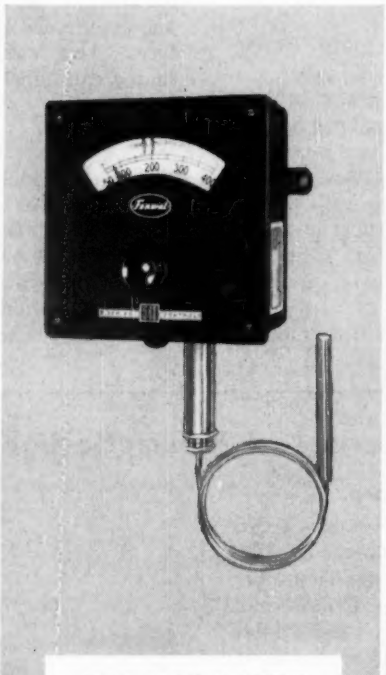

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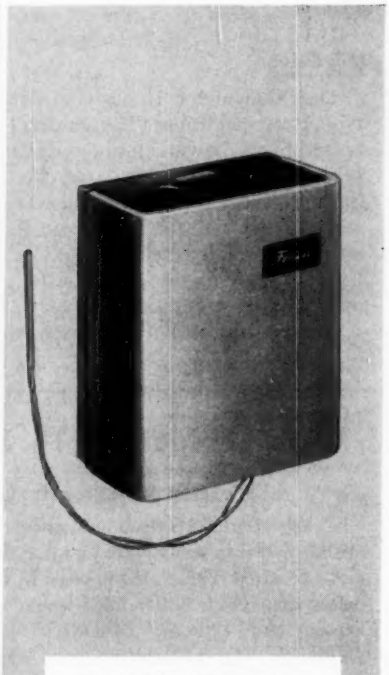

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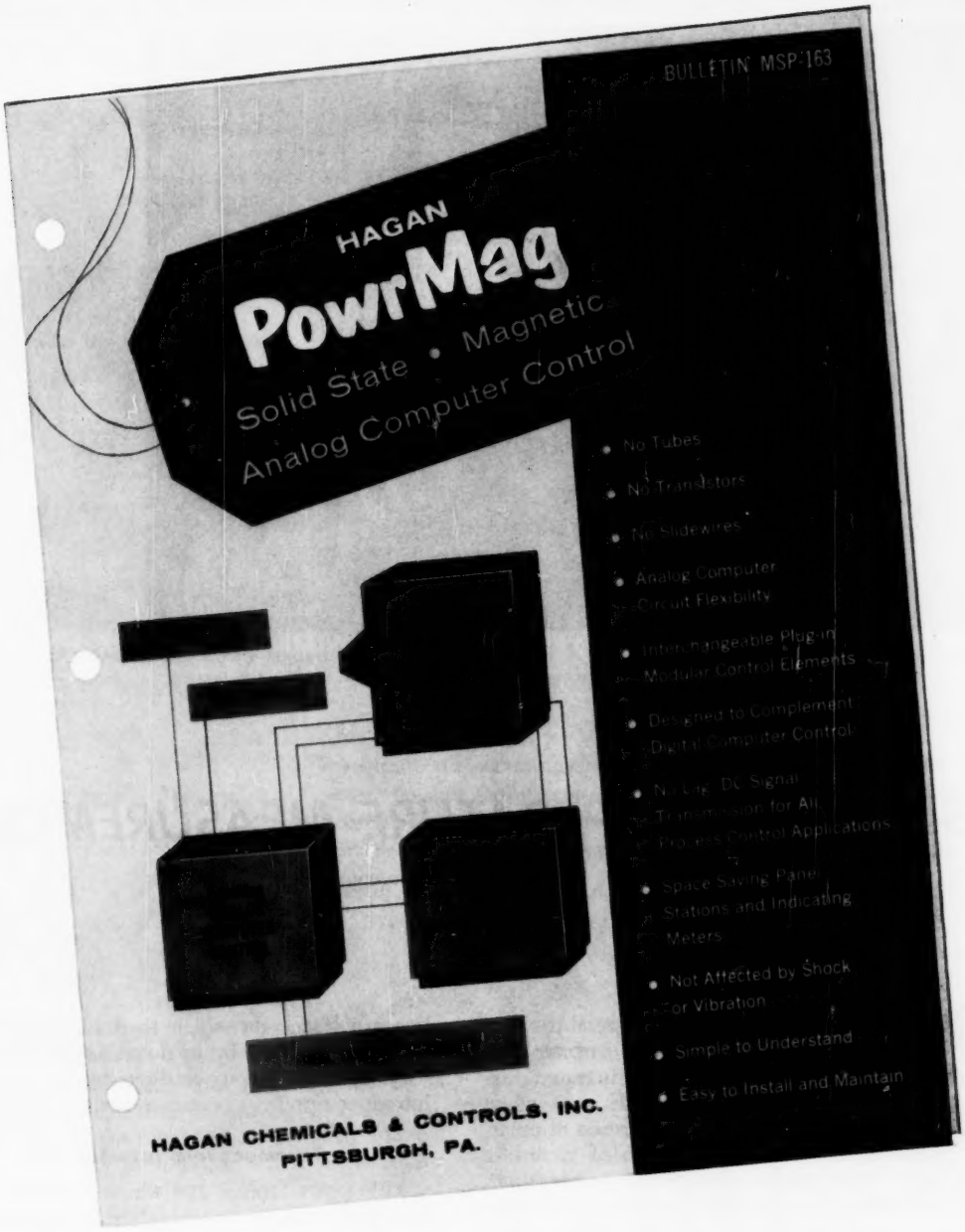
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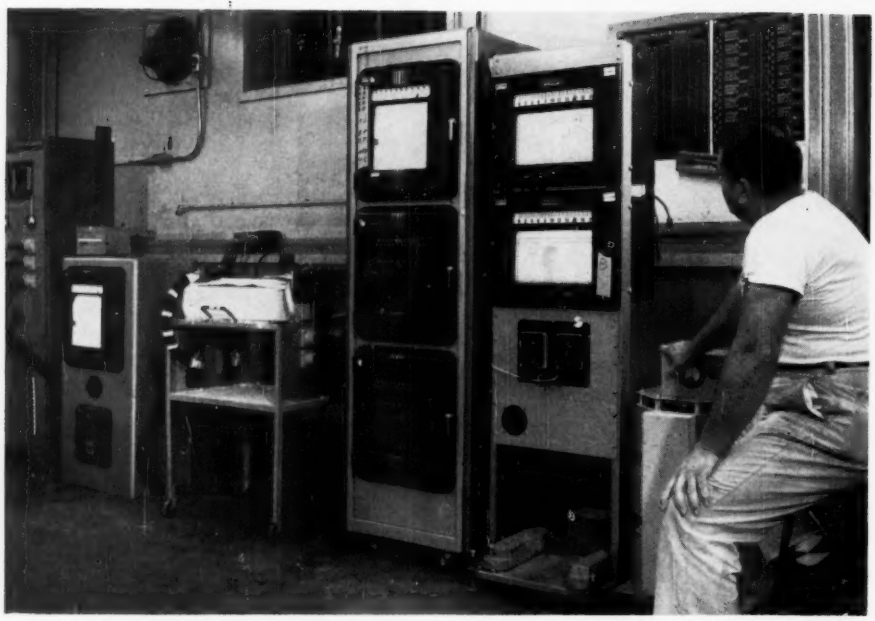

FIG. 1. EQUIPMENT used in terminal resistance heating.

SURFACE TEMPERATURE MEASUREMENT

OBSERVATION during high-temperature testing disclosed that with static surface temperature in the 1600°F range, measurement discrepancies can be as much as 50°F even when reasonable care is taken in the application of measuring devices and in the calibration of recording equipment. With rapid changes in temperature, readings differed occasionally by as much as 150°F, and 15 seconds sometimes were required for equalization.

Significance of Errors

An argument can be made that the percentage of error remains small. However, the actual significance of such errors is that errors of any magnitude whatsoever become more critical as temperatures go up. Also, a percentage error means that error magnitude increases with higher temperatures. For example, the effect of temperature on the ultimate strength of Inconel 700 in terms of the strength-to-weight ratio used in design work is such that at a design temperature of 1700°F, the weight difference caused by a 50°F error would be 28%. There are other places where a 50°F error can be important.

In regard to dynamic temperatures, there is even less experience on which to draw. Some thermocouples lag others by as much as 15 seconds, and vary in instantaneous readings by 150°F; this can introduce significant errors in design.

Thermocouple Investigation

Although Chromel and Alumel as well as platinum and rhodium bring higher temperatures within the rated range of thermocouple wires, the investigator used an iron-constantan combination because its normal accuracies are not destroyed during the limited period of each test.

The thermocouples were attached by spotwelding to avoid adding mass. Added mass absorbs heat, lowers the temperature of the contacting surface, and delays response during rapid temperature changes.

Throughout this investigation, merely the comparative nature of readings was of interest. Although true temperature readings were sought, it was recognized early that to label one temperature as true and another as indicated would require a type of arbitrary selection that would be open to criticism. Therefore, reference readings were selected on the basis of conditions considered most favorable to achieving accuracy, but these were not

FIG. 2. THERMOCOUPLE being welded to outside of cylindrical insert; additional couples were welded to inside surface.

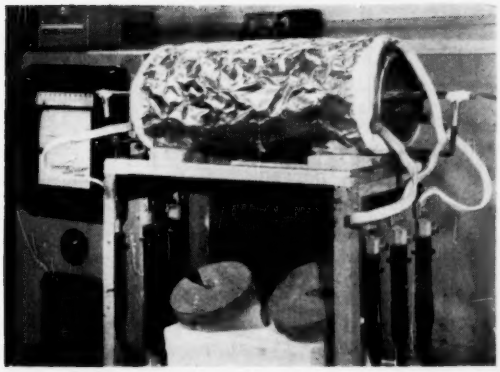

FIG. 3. OVEN WITH ends open. End blocks are shown under oven.

WALTER K. MOEN

North American Aviation, Inc.

Accurate surface temperature measurement has gained broad recognition, but the attention has been comparatively recent and accounts for lack of standardization in measuring techniques. This article discusses the magnitudes and sources of error sometimes encountered during the measurement of surface temperatures.

referred to as the true temperature of the surface, nor of the material.

The heat source used throughout the investigation was terminal resistance heating. Terminal resistance heating was selected because of its adaptability to the test conditions, which were quite severe for the case requiring simulation of rapid temperature changes. The rates achieved were as high as 1800°F in 2 seconds. Fig. 1 shows a 12-kva current transformer, a 12-kva motor-operated Powerstat, and some of the instruments used for recording temperature readings in one setup. A Leeds & Northrup multilog Type C Speedomax automatic recorder and two Minneapolis-Honeywell, single-point, 0.25-second, Model Sy 153 recorders are shown.

Effects of Convection

The most revealing results of the investigation dealt with the effects produced by convection. To evaluate these, a cylindrical furnace was constructed of 0.006″ 17-7PH stainless steel into which the test specimens were placed. The test specimens (thermocouples) were attached to a cylindrical insert made of the same material as the furnace but having a gage of 0.020″. Fig 2 shows the thermocouples being welded to the insert. One side of the probe-type handpiece is clamped to the sheet, and the other side of the handpiece is held firmly against the thermocouple junction being welded. Prior to welding, the skin surface is cleaned with a solvent and the thermocouple wire is coiled and taped to the skin surface.

Fig. 3 shows the furnace covered by fused quartz and aluminum-glass insulation. Current is passed through the furnace wall, and the insert is suspended inside by four insulated wires running from the rims of the furnace. With this arrangement the insert can be heated from ambient to 1600°F in one minute. Thermocouples were attached to both the outside and inside of the insert; the inside was filled with fused quartz in some cases.

The effect of convection was studied by holding the furnace horizontal, with the ends open and closed, and vertical, with the ends open and closed. Fig. 4 shows the effect on temperature caused by opening the ends when the drum was horizontal. Effects of emissivity were negligible in comparison.

Note how the thermocouple readings plunged when the ends were opened. A record made when

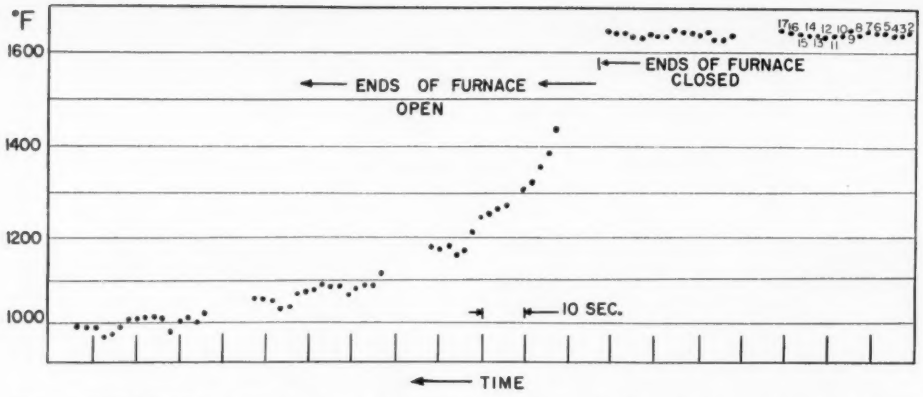

FIG. 4. INFLUENCE of surface emissivity and convection on indicated temperatures with oven horizontal. Each cluster (thermocouples 2 to 17) is one scan of thermocouples on drum surface.

the drum was held vertical showed nearly identical temperatures while closed, and a somewhat more severe drop when the ends were opened. After 10 seconds the readings averaged 900° F and varied more than 200°F for different locations on the drum. With the drum horizontal and the ends closed, temperatures varied no more than 20°F; when vertical with the ends open, the temperature spread was more than 200°F. Current was constant during the portion of the runs shown. Therefore, the effect of convection not only increased the difference between upper and lower thermocouple readings from 20°F to 200°F but also caused the approximately 750°F difference between the 1650°F and 900°F average surface temperature, for the same heat input.

Evaluation of Thermocouple Design

A literature search and consultation with many engineers revealed six types of thermocouple forms used most often. The favored two of these six are termed *Type X* and *Type P;* Type X has a crossed-wire junction and Type P has parallel wires which do not touch each other but are joined to a common surface (Fig. 5).

In general, there are two errors in a thermocouple used for measuring surface temperature. The first is due to a reduction in surface temperature caused by heat transfer through the thermocouple leads. The second is due to a difference in temperature between the point of contact with the skin surface and the actual thermocouple junction, again because of heat transfer along the thermocouple leads.

In the Type X thermocouple one lead is placed on top of the other and welded; hence the junction is approximately a wire diameter above the point of contact with the specimen surface. Any heat flow through the junction is thus accompanied by a temperature gradient between the junction and the specimen surface.

Because of this error in the Type X, or crossed-wire junction, the paralled-wire type is recommended. In this type, the junction is at the point of contact with the surface.

It was considered worthwhile to run tests to compare the difference between the two types of thermocouples. A ¼" plate provided the heating surface to help assure a uniform distribution of heat over the surface as well as to minimize the effect on plate surface temperature from heat loss through the thermocouple. To create conditions most conducive to such a gradient loss, lead wires were held perpendicular to the plate. For purposes of checking the temperatures or most closely approximating the true temperature, lead wires of the reference thermocouples were strapped securely to the plate. The test thermocouples comprised both Types X and P. The check thermocouples were only Type P. All junctions were welded to the plate, and the specimen and the thermocouples were exposed to convection and to room temperature.

Reference temperatures at the point of contact of the test thermocouples with the plate were determined by plotting the surface-temperature distribution based on readings of the check thermocouples. Table 1 shows the interpolated reference

TABLE 1—COMPARISON OF TYPE X AND TYPE P THERMOCOUPLES

Interpolated Ref. Temp. (°F)	Couple No.	Type X Reading (°F)	Error (°F)	Couple No.	Type P Reading (°F)	Error (°F)
1205	7	1160	45			
1210	6	1150	60	9	1215	5
1215	13	1145	70	8	1200	15
1215				15	1210	5
1220	12	1140	80	14	1195	35

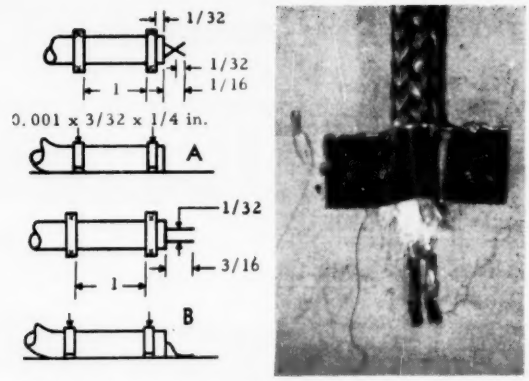

FIG. 5. A SHOWS crossed-junction, Type-X thermocouple; junction is almost one wire diameter above surface. B shows parallel-wire, Type-P thermocouple where each leg is welded to surface. C shows actual parallel-wire couple installation.

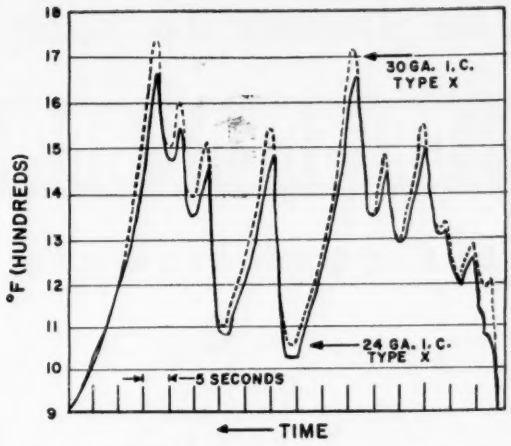

FIG. 6. RESPONSE of B & S 24-gage and 30-gage wire.

temperatures and the temperatures actually recorded by the test thermocouples in one such test.

The results show that the Type X thermocouples were reading an average of 64°F below the plotted plate temperatures, and that the Type P thermocouples were reading an average of only 10°F below the plotted plate temperatures. Although having lead wires vertical to the surface is an extreme situation the difference of more than 50°F is of considerable importance. (Fast rates of temperature change were not attempted.)

Some engineers questioned the ability of the constantan leg of the Type P thermocouple to remain welded to a skin during normal testing operations. This prompted investigation of Type P thermocouple life in several environments. Vibrations as high as 15 g at 70 cps were applied with temperatures up to 1200°F; the difference in failures between the two types of thermocouples was found to be negligible. Temperature cycling tests also were run, with extremes extending roughly from 250°F to 1650°F. In these tests, the constantan leg of the parallel-wire thermocouple separated from the surface before failures occurred in the crossed-junction thermocouples. However, almost no failures occurred until after more than three hours exposure to such conditions. For the normal run of testing, a three-hour life is more than sufficient.

Through calculation and experiment the parallel-wire, Type P thermocouple was shown to be appreciably superior.

Evaluation of Wire Size

Fig. 6 shows the results of a test comparing the popular B & S 24-gage and 30-gage wires in a thermocouple with a crossed-wire junction (Type X). The transients in this case were approximately 500°F in 2 seconds. The curves shown were traced from the recordings made by two Minneapolis-Honeywell, single-point, ¼-second instruments. The 30-gage thermocouple responded more quickly and revealed higher peaks of temperature than the thicker 24-gage wire. For measuring extremely fast rates of temperature change, therefore, the 30-gage thermocouple wire is recommended.

Conclusion

The primary conclusion drawn from the investigation is the following: The measurement of higher surface temperatures in laboratory testing requires more of a change in thermocouple design than simply shifting to a wire with a higher temperature rating. Actually, consideration must be given first to the conditions affecting convection when surface temperatures of 1000°F or more are involved. In this range, the investigation disclosed that readings can be altered roughly 50% by changing only the convective conditions.

A parallel-wire Type P junction (Fig. 5) is considered best. Also B & S 30-gage wire should be used, and should be attached by spotwelding.

Acknowledgements

All of the work referred to was conducted by the writer in the Missile Division Laboratory. Acknowledgement is given to J. M. Smith of the Missile Division, for support in this investigation.

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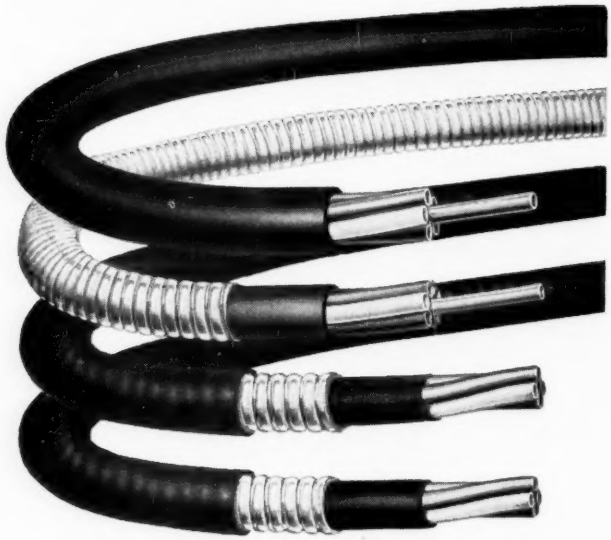

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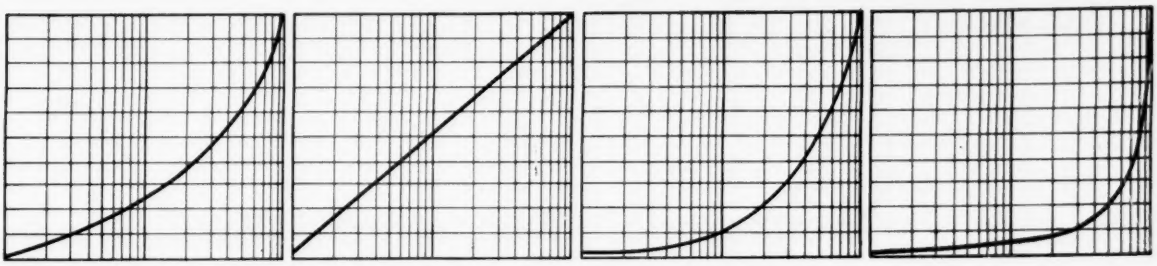

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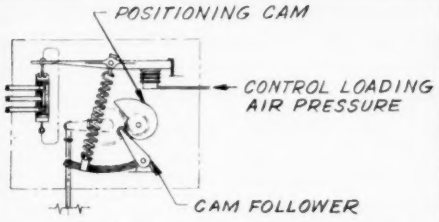

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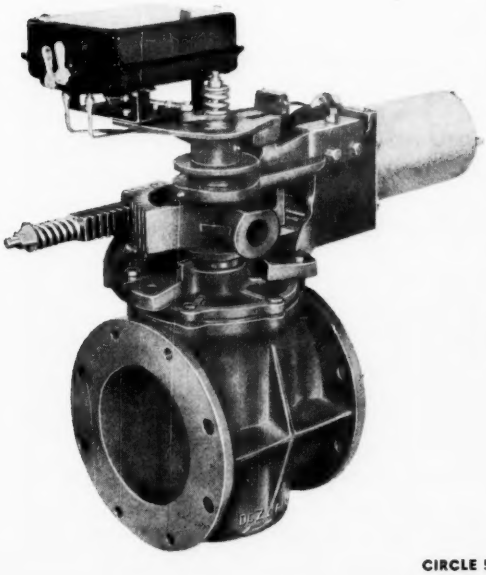

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Thermocouple Temperature Measurement

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THERMOCOUPLE TEMPERATURE INDICATORS commonly are especially constructed and calibrated for the particular thermocouple materials used. However, ordinary millivoltmeters and milliammeters can be used to indicate temperature provided the temperature difference between the thermocouple junctions is at least 100°F.

The two thermocouple materials may run all the way to the meter or they may be brought to the meter by copper extension leads (Fig. 1). The latter circuit sometimes gives a greater deflection for a given furnace-to-room temperature difference because of the low resistance of copper. The cold junction temperature must be known, or can be determined by an auxiliary thermometer. The two connections between the thermocouple materials and the copper extension wires should be close together because any temperature difference between them will introduce serious error.

The temperature difference between the hot and cold junctions accounts for the potential developed by the thermocouple. An approximation of the temperature difference between junctions for each millivolt potential difference (K) is given in Table 1 for several common couple materials, in F° per millivolt.

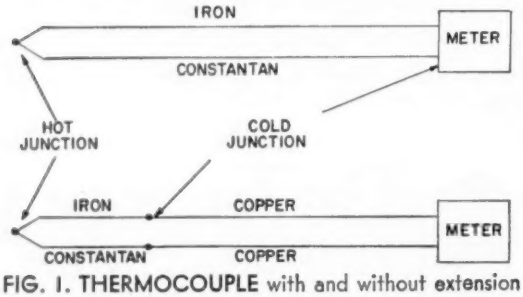


FIG. 1. THERMOCOUPLE with and without extension wires.

Some of the EMF developed is lost in IR drops along the wires to the meter. If the indicator is a millivoltmeter, it will read only the voltage across its terminals. This will always be less than the open-circuit EMF, and the difference will be proportional to the ratio of lead resistance to meter resistance—that is, the actual temperature difference between junctions in F° per millivolt across the meter terminal is:

$$K\left(\frac{\text{total circuit resistance}}{\text{meter resistance}}\right) \qquad (1)$$

If the indicator is a milliammeter the actual temperature difference between junctions (in F°) per milliampere is:

$$K\ (\text{total circuit resistance}) \qquad (2)$$

High-sensitivity millivoltmeters intended for use with thermocouples often have resistance as high as 100 to 600 ohms, and electronic millivoltmeters may have resistance of more than a million ohms. With such high meter resistances, the value of the second term (total resistance/meter resistance) of expression (1) usually will be so close to unity that no appreciable error will be introduced if the term is ignored.

The resistance, in ohms, of an inexpensive moving coil (d'Arsonval) panel milliammeter is usually between 100 divided by the full-scale range in milliamperes and 20 divided by the full-scale range in milliamperes. The exact value often can be obtained from the manufacturer's literature.

Table 1 shows the approximate resistance, per foot, for some of the most commonly used thermocouple materials. The resistance figures are totals for one foot of each of the two materials. As the diameter, and hence the resistance, of a particular specimen of wire may differ from the standard, or nominal value, better

Without Special Instruments

DALE KELLY
New England College

accuracy often will be obtained if the entire circuit is calibrated against known temperatures. (If more accurate values of K are desired, see National Bureau of Standards Research Paper 2415.)

Temperature Calculation

Assume a thermocouple circuit like that shown at the top in Fig. 1 comprises 10′ each of 20-gage iron and constantan wire, and a millivoltmeter with a resistance of 100 ohms. The reading on the meter is 40 millivolts. Determine, within 10%, the temperature differences between the hot junction and the meter.

Solution—Table 1 shows that the resistance of a 20-gage iron-and-constantan couple averages 0.35 ohm per foot. Total couple resistance is (10) (0.350) = 3.5 ohms. This is so small compared to the meter resistance (100 ohms) that ignoring the second term in expression (1) will introduce an error of only 3½%. The maximum variation of K from its tabulated value is shown as 2 parts in 33, or 6%.

The temperature difference, within 9.5%, is therefore:

$$(40 \text{ mv})(33°\text{F/ mv}) = 1320°\text{F}$$

Let us consider a circuit like that shown in the bottom of Fig. 1 comprising 6′ each of 28-gage copper and constantan, a two-conductor 28-gage copper cable 15′ long, and a 3″ 10-milliampere panel meter (Weston Model 301). The meter shows a current of 0.8 milliampere; the temperature is 60°F at the meter and 100°F at the junction between the two-conductor cable and the thermocouple leads. Determine, within 50°F, the hot-junction temperature.

Solution—According to the table, the total resistance of the 6′ of copper and constantan is (6) (1.9) = 11.4 ohms, and the resistance of the two-conductor cable is (15) (0.13) = 1.9 ohms. In the absence of specific data the resistance of the milliammeter could reasonably be estimated as 50/full-scale range in milliamperes, or 5 ohms. The total circuit resistance is approximately 11.4 + 1.9 + 5 = 18.3 ohms. The temperature difference is approximately (0.8) (40) (18.3) = 585°F, which gives a hot-junction temperature of 100 + 585 = 685°F. The temperature of 60°F at the meter has no bearing on the problem.

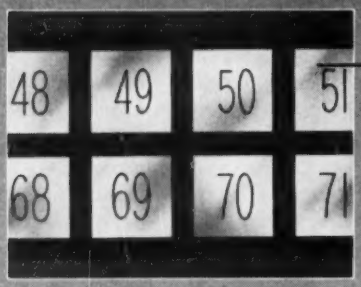
The calculated temperature of 685° is probably not correct within 50°F because (1) the table shows that the tabulated value of K is subject to an error of 12½% at some temperatures, (2) the thermocouple and lead wires constitute most of the circuit resistance, and their resistances may not agree with the nominal or standard resistances for their gage, (3) the meter resistance is only an estimate (the manufacturer's catalog gives, for this particular meter, a resistance of 2 ohms rather than 5) and, (4) the accuracy of reading the meter is not good because the reading is less than 10% of full scale.

The first three errors can be eliminated by consulting Bureau of Standards' tables instead of using the value of 40 ± 5 for K, and by direct measurement of the circuit resistance. Alternatively, the entire circuit could be calibrated against known temperatures. The last error (4) could be eliminated by the use of larger gage wires.

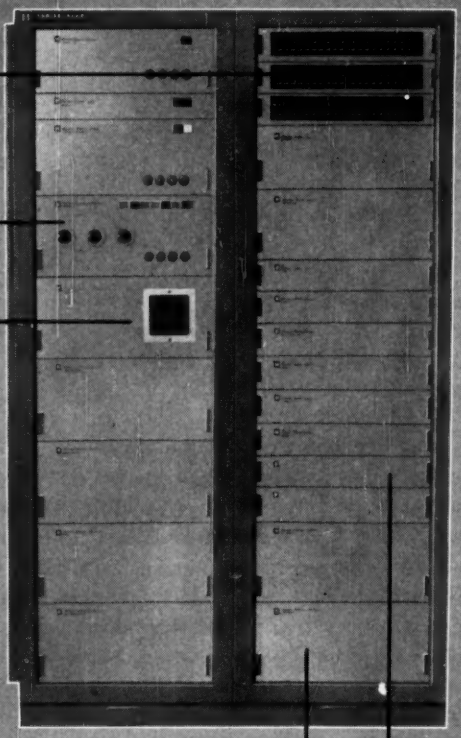
TABLE 1—AVERAGE RESISTANCE PER FOOT (IN OHMS) OF COMMON THERMOCOUPLE MATERIALS

		Iron-Constantan	Copper-Constantan	Chromel-Copper	Chromel-Alumel	Copper-Copper
Maximum practical temperature (°F)		1400	660	2000	2200	
K (F° per mv)		33 ± 2	40 ± 5	27 ± 3	44 ± 2	
Wire Gage No.						
Combined resistance per foot (ohms)	2	0.0054	0.0046	0.0108	0.0091	0.000313
	4	0.0086	0.0073	0.0172	0.0145	0.000497
	6	0.014	0.0116	0.027	0.023	0.00079
	8	0.022	0.0185	0.044	0.037	0.00126
	10	0.0345	0.0293	0.069	0.059	0.00199
	12	0.055	0.0465	0.110	0.093	0.00318
	14	0.087	0.074	0.175	0.147	0.00505
	16	0.139	0.118	0.279	0.234	0.00803
	18	0.221	0.188	0.442	0.380	0.0128
	20	0.350	0.297	0.706	0.586	0.0203
	22	0.56	0.475	1.12	0.940	0.0323
	24	0.89	0.75	1.77	1.49	0.0513
	26	1.41	1.20	2.82	2.39	0.0816
	28	2.26	1.90	4.50	3.8	0.130
	30	3.57	3.03	7.1	6.0	0.206

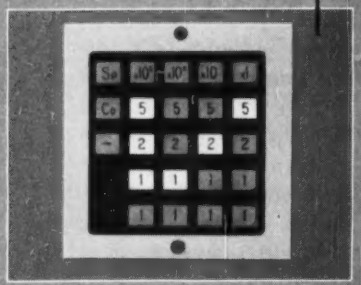
New packaged



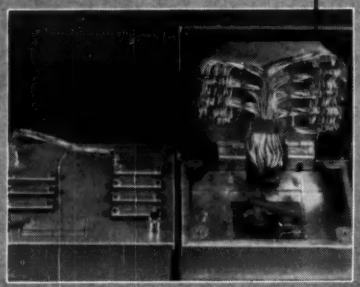
THREE 40-POINT ANNUNCIATORS make it easy for the operator to tell at a glance which variables are off-normal.



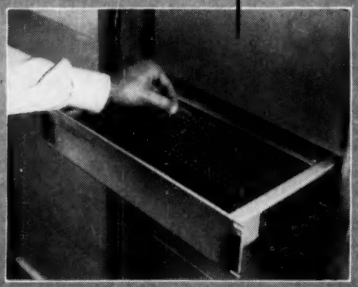
DIGITAL VISUAL DISPLAY and variable selector switches make it easy to select any single variable and watch all trends and changes continuously.



SERVICING IS SIMPLIFIED by an indicator-light panel showing the completion of each step in the analog to digital conversion. The sequence programmer can be changed from automatic to hand advance to permit operator to check each step.



UNIQUE INPUT SELECTOR is unusually dependable because of its sealed, oil-immersed construction. Servicing is normally limited to visual inspection every 6 months. Drawers pull out so voltage checks can be performed without shutting down system.



PINBOARD PROGRAMMING adds flexibility. You can change the logging or scanning sequence at will . . . substitute one type of input for another. Range, span, and zero adjustment are set by inserting pins in their proper places. No calculations are required. The pinboards are pinned in familiar units of measurements.

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The Series 3120 accepts signals from primary measuring instruments—thermocouples, flow, pressure or other transducers. It measures these signals, digitizes them, and prints their values in immediately usable form. A thermocouple reference oven can be supplied to accommodate three types of thermocouple inputs—types T, J, and K—which are automatically linearized over their entire range to within 0.1% accuracy.

The operator can select either automatically or manually initiated logging cycles. He can set the system to log all variables automatically at preset intervals, or manually energize the system to operate on demand, between logging cycles.

Between logging cycles, the system can scan off-normal alarm points—high, low or both—at a rate of 7 points per second. Upon detecting an off-normal point, the system sounds an alarm, lights a point-identification light, and prints the time, point number and off-normal value on adding machine tape. During log cycles, off-normal points are printed in red on the log sheet.

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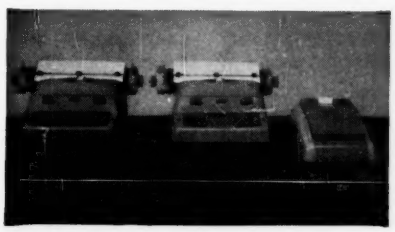

TWO TYPEWRITERS permit a single line log allowing columnar comparisons. Separate alarm printer records all off-normal variables.

STANDARD MODULAR COMPONENTS are assembled on chassis mounted as individual drawers in relay racks. All drawers are connected by plugs for easy servicing.

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ERRORS IN THERMOCOUPLE

Major errors are overlooked frequently in the design of thermocouples circuits, generally because of misinterpretation of thermocouple wire guarantees. Errors can accumulate in a thermocouple circuit when junctions between dissimilar metals, including lead-wire junctions and instrument connections, are not at 32°F.

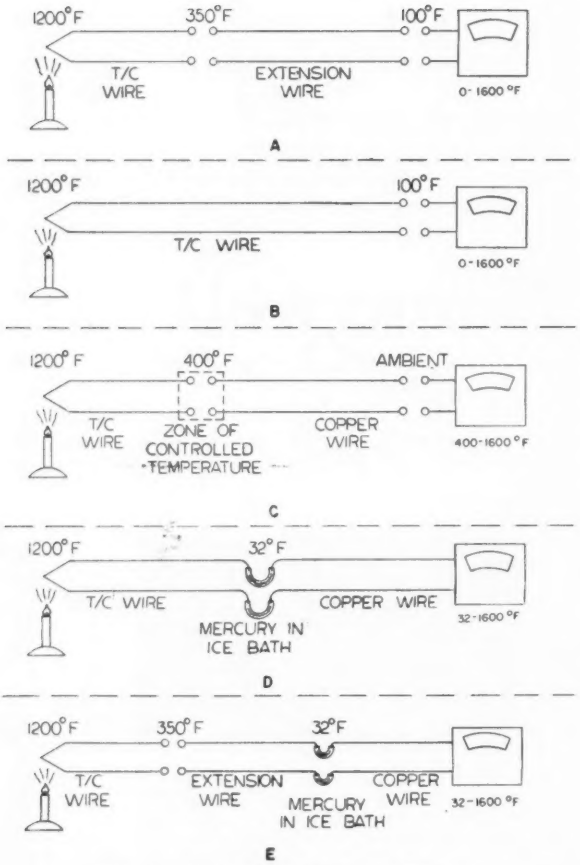

FIG. 1. THERMOCOUPLE installations.

MOST industrial thermocouple circuits presently are composed of either (1) iron and constantan or (2) chromel and alumel. There are standard guarantees on both types: Based on a 32°F reference temperature, guarantees (stated in ISA Bulletin R.P.1.3) are: ±4°F from 0°F to 530°F and ±¾% of the Fahrenheit temperature from 530°F up to the high temperature for thermocouple wire. *Extension lead-wire guarantees* are ±4°F from 0°F to 400°F for the given materials.

On the basis of these wire guarantees, the maximum error a thermocouple *with ice-bath reference temperature* is: 4°F at 200°F, 4°F at 400°F, 4½°F at 600°F, 6°F at 800°F, 7½°F at 1000°F, 9°F at 1200°F, etc. These maximum error values apply only when one end of the thermocouple is at 32°F and the other junction is at the given temperature. When the indicating instrument is reference-junction compensated, an additional error is added—the thermocouple error introduced at the connection to the instrument.

Let us examine a chromel-alumel thermocouple with its measuring junction at 1200°F and with a reference (cold-junction) temperature of 100°F. According to the guarantee, the error at the measuring junction can be as much as 9°F. In addition, the error at the reference junction (100°F) can be 4°F. Hence the total maximum error can be 13°F. Maximum error may not always happen, but is permitted by the guarantee.

Extension Wire Factors

Most thermocouple installations comprise a thermocouple, *extension wires* and an instrument (Fig. 1A). Assume a chromel-alumel thermocouple with one junction at 1200°F and a reference temperature of 350°F.

CIRCUITS

ROBERT J. ALMOND
Harco Laboratories, Inc.

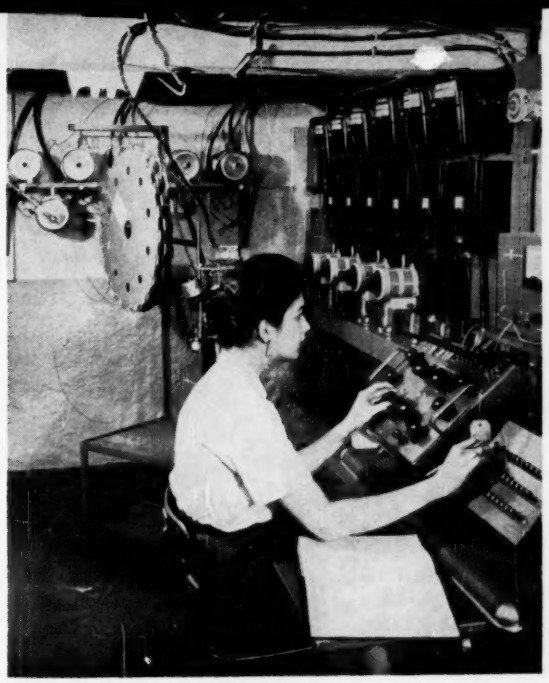

FIG. 2. CHECKING thermocouples.

The extension wire has one end at 350°F and the other end at 100°F. The instrument has automatic reference-junction compensation for the 1600°F range; accuracy guarantee is ¼% of full scale. The error of the thermocouple wire will be ±9°F at the 1200°F point and ±4°F at the 350°F point. The maximum error of the lead wire will be ±4°F at the 350°F point and ±4°F at the 100°F points. The maximum error of the instrument will be ±4°F. If all these errors are of such polarity that they add, the total maximum error will be 25°F, or slightly over 2% of the actual temperature at the measuring junction. *This combination of errors can happen.* It is permitted by component guarantees and is the smallest possible absolute guarantee of system accuracy where the system is composed of components selected randomly.

Improving Accuracy

Methods of improving system accuracy are as follows, referring to the circuits shown in Figs. A to E, with errors listed in Table 1. The original system has maximum error of 25°F, as described.

Method 1

a. Thermocouple wire is available with half the standard tolerance—±2°F from 32°F to 530°F and ±⅜% from 530°F and up. Using this wire would give the system under study a maximum error of 18.5°F.

b. In addition to la, the extension wire can be replaced with that having the closer guarantee—±2°F from 32°F to 40°F. The maximum system error would then be 14.5°F.

TABLE 1—ERRORS IN °F

Alternatives	System	Thermocouple Wire Hot End	Thermocouple Wire Cold End	Extension Wire T/C End	Extension Wire Instr. End	Controlled Ref. Temp.	Inst.	Total
Original	A	9	4	4	4	—	4	25
1 (a)	A	4.5	2	4	4	—	4	18.5
1 (b)	A	4.5	2	2	2	—	4	14.5
2 (a)	B	9	4	—	—	—	4	17.
2 (b)	B	4.5	2	—	—	—	4	10.5
3 (a)	C	9	4	—	—	2	2	17
3 (b)	C	4.5	2	—	—	2	2	10.5
4 (a)	D	9	—*	—	—	0**	4	13
4 (b)	D	4½	—*	—	—	0**	4	8.5
5 (a)	E	9	4	4	—*		4	21
5 (b)	E	4½	2	2	—*	0**	4	12.5
6	A	2	1	1	1	—	4	9
7 (a)	D	2	—*	—	—	0**	4	6
7 (b)	D	2	—*	—	—	0*	2	4
7 (c)	D	—	—*	—	—	0**	—	2
8 (a)	A	9	0	0	4	—	4	17
8 (b)	A	4.5	0***	0***	2	—	4	10.5

*There is no error voltage at 32°F because this is the standard reference temperature for calibrating. Any error at 32°F is attributed to the measuring junction. The error in a junction at 32° cannot be isolated and measured. For this reason the error is assumed to be 0°F and consequently if any error exists at 32° it is attributed to the measuring junction at all other temperatures.

**The absolute error of temperature in a carefully prepared ice bath will be no greater than 0.02°F.[1] For the present discussion this is considered negligible.

***There will be an error here equal to the magnitude of any mismatch. In a physical installation the temperature, at the connection of the thermocouple to the extension wire, will vary over a relatively wide range. The worst mismatch over this connection temperature fluctuation range will be the error here.

Method 2

a. The thermocouple could run continuously from the hot temperature to the instrument, as in illustration B. For standard wire this would yield a maximum error of 17°F.

b. With close-tolerance wire the maximum error would be 10.5°F, as follows (Table 1):

TC hot end	4.5°
TC cold end	2.0°
Ref. temp.	2.0°
Instrument	2.0°

Method 3

a. The thermocouple cold end could be maintained at a temperature of, say, 400°F ±2°F with copper wire run to an uncompensated instrument (Fig. C). The lowest temperature on the instrument would then be 400°F; its range would decrease from 1200°F to 800°F and, for a ¼% instrument, the error would be ±2°F.

Such a system would have a maximum error (with standard wire) of 17°F.

b. With close-tolerance wire the maximum error would become 10.5°F, as follows:

TC hot end	4.5°
TC cold end	2.0°
Ref. temp.	2.0°
Instrument	2.0°

Method 4

a. The thermocouple could have an ice-bath reference temperature (Fig. D). With standard-tolerance wire the system maximum error would be 13°F.

b. With close-tolerance wire it would be 8.5°F.

TC hot end	4.5°
Instrument	4.0°

Method 5

a. Extension wire can be interposed between the thermocouple and the ice bath (Fig. E). With standard wire the maximum error would be 21°F.

b. With close-tolerance thermocouple wire and close-tolerance extension wire the error would be 12.5°F.

Method 6

a. The thermocouple can be calibrated to an accuracy of ±2°F at 1200°F and ±1°F at 350°F. The extension wire can be calibrated to an accuracy of ±1°F at 100°F. System maximum error would be 9°F, with appropriate data compensation.

Method 7

a. The thermocouple can be individually calibrated, have an ice bath reference, and copper leads to the instrument (Fig. D). The system error would be 6°F.

b. The instrument also can be calibrated to ±2°F. System accuracy is then 4°F.

c. The entire system can be calibrated over-all to an accuracy of ±2°F, yielding a system accuracy of 2°F.

Method 8

a. Instead of selecting the components randomly, the lead extension wire can be selected to match the thermocouple wire at the thermocouple cold-end temperature—that is, selecting extension wire whose calibration data shows same error at all points in ambient temperature range expected at the connection. This would give the effect of running the thermocouple directly to the instrument. System accuracy is 17°F for a perfect match.

b. The same system with close-tolerance wire would have an error of 10.5°F.

Other Sources of Error

Thus far, only junction errors (due to the Peltier emf) have been discussed. In addition to this effect two other thermoelectric effects of a more exotic nature are present in all thermoelectric circuits. These are the Peltier *effect* (heat-pump effect) and Thompson effect.

The Peltier "effect" is the absorption or evolution of heat at the junction of two dissimilar metals during passage of an electric current; the corresponding emf is the Peltier emf. This effect tends to cool the junction when it is used to measure a high temperature. In a measuring circuit this effect is negligible[2] and for most practical purposes it can be ignored in a physical measuring circuit.

The Thomson effect is the generation of an emf in contiguous parts of a metal where these parts are at different temperatures. It is an emf generated along each homogeneous wire. The Thomson effect has less influence on the junction temperature than the Peltier effect. In most practical measuring circuits, errors due to heat liberation and absorption by the Thomson effect may be ignored. The sum of all emf's in the circuit —the two Peltier emf's at each junction and the two Thomson emf's along each conductor is sometimes referred to as *Seebeck* emf in honor of the first man to discover the thermocouple effect. It is apparent that the only effects of practical interest in temperature instrumentation are the guarantee tolerances because errors due to Peltier and Thomson *effects* are of negligible magnitude. (Other sources of error not discussed are the errors due to inhomogeneity of the conductors, connectors and any other materials in the circuit.)

The method herein used to calculate maximum errors may be applied to any type of thermocouple material. Standard tolerances for most thermocouple wire are stated in R.P.1.3. published by the Instrument Society of America.

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THERMISTORS

RAYMOND I. SCHIFF

Yellow Springs Instrument Co., Inc.

Interchangeable thermistor elements with stable temperature-resistance characteristics offer new temperature-measuring techniques and possibilities.

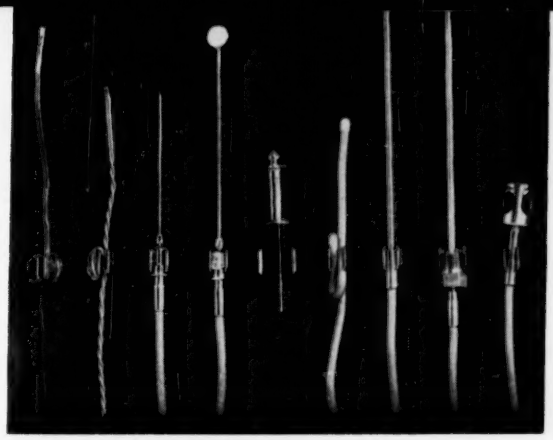

FIG. 1. THERMISTOR temperature probes: 402—rectal probe for small animals; 409—skin or surface temperature probe; 507—hypodermic needle for humans or large animals; 408—skin or surface temperature; probe jack; 401—esophagal or rectal probe for humans and large animals; 403—stainless-steel liquid temperature probes; 410—pipe plug probe; 405—air-temperature probe.

THERMISTOR TEMPERATURE MEASUREMENT follows the usual principles of resistance thermometry. A conventional resistance-measuring circuit is employed, comprising a thermistor (thermal-sensitive resistor), a source of current, and a device (usually a bridge) to measure current flow.

A thermistor is made of a semiconducting material that exhibits a high negative temperature-coefficient of resistance—the resistance decreases as temperature rises, and increases as temperature falls. (Ordinary resistors normally posses small positive temperature-coefficients and increase in resistance only slightly as temperature rises.)

The high temperature-coefficient of thermistors means high sensitivity, higher than the more common resistance thermometers or thermocouples. This permits precise measurement of minute spans of temperature, a capability not feasible with ordinary resistance thermometers or thermocouples.

Another advantage of thermistors is ability to be designed with sufficiently high resistance values to make lead-resistance errors negligible. The terminal resistance of thermistors at room temperature ranges from about 1 ohm to about 10^8 ohms, depending on composition, shape and size. Therefore, the thermistor elements can be located remotely and instrument lead length can be made non-critical.

Thermistors as small as 0.014″ diameter function as efficiently as larger thermistors of 0.75″ diameter. Thermistor probes are not only versatile in design but also mechanically simple.

As a result of modern manufacturing processes, production thermistors now consistently follow a standard temperature-resistance curve. Also, performance of the thermistors remains within the interchangeability specification for long periods of time. These advances in the state of the art have paved the way for a new approach to thermistor temperature measurement today; many probes are available for measurement and control of liquids, gasses, semi-solids and surfaces (Fig. 1). Further, these interchangeable thermistors will consistently follow the same temperature-resistance curve within an accuracy of ±0.2°F.

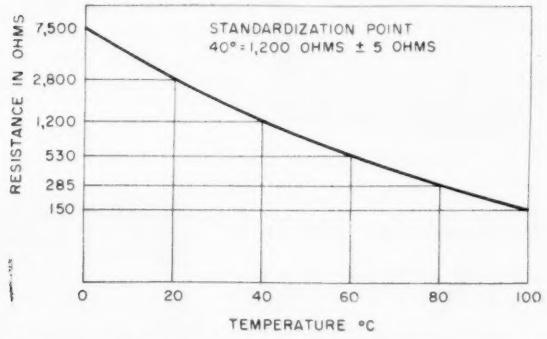

FIG. 2. STANDARD temperature-resistance curve followed by all 400-series thermistor probes.

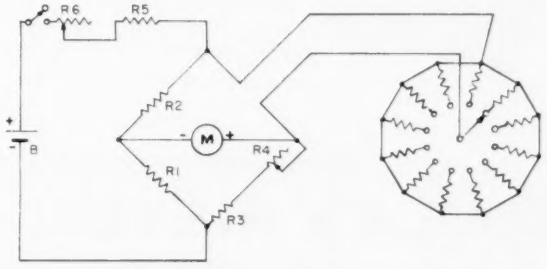

FIG. 3. SCHEMATIC diagram of a Model 44 twelve-channel Tele-Thermometer.

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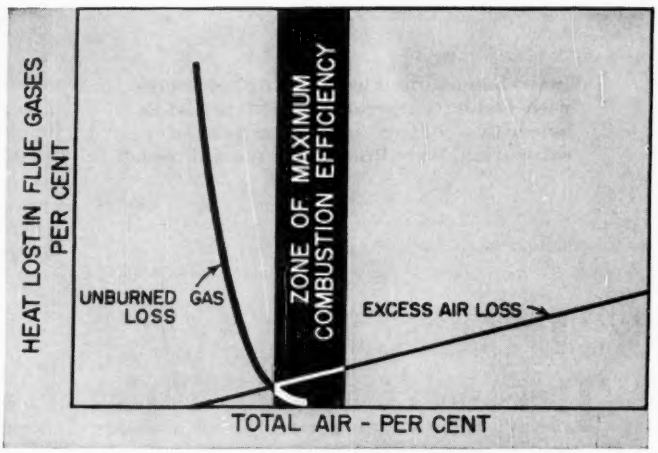
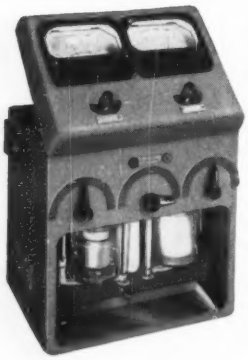
Both instruments measure: (1) excess air—regardless of the fuel or combinations of fuel being burned, (2) mixing efficiency of your fuel burning equipment by showing per cent combustibles in the flue gas.

Both units are designed to increase efficiency in the furnace operations of the steel industry, on glass tanks, cement and lime kilns, ceramic and refractory kilns, steam boilers and also on direct and indirect-fired furnaces in the metal processing industries. To prevent your money from becoming waste gas, look into these two efficiency provers. A Bailey engineer will be glad to give you details or write us for product specifications.


HEAT LOST IN FLUE GASES PER CENT
UNBURNED GAS LOSS
ZONE OF MAXIMUM COMBUSTION EFFICIENCY
EXCESS AIR LOSS
TOTAL AIR - PER CENT

Maximum Combustion Efficiency is secured by keeping the sum of Excess Air Loss and Unburned Gas Loss to a minimum. To do so by the direct method simply measure both oxygen and combustibles in flue gas.

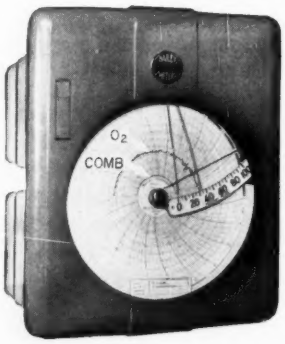
For portable use—
HEAT PROVER Analyzer



The famous Cities Service HEAT PROVER analyzer is now Bailey built and sold. Weighing only 25 pounds, it is a self-contained automatic analyzer including a sampling tip and hose plus a thermocouple for temperature measurement.

Instrument dials are dual range for greater accuracy and sensitivity.

For permanent installation
Oxygen-Combustibles Recorder



The Bailey Oxygen-Combustibles Analyzer-Recorder coordinates both records on one chart. These records enable the operator to keep fuel burning equipment performing continuously in the zone of maximum combustion efficiency. Excess air may be reduced to the point where combustibles begin to show.

G 40-1

Instruments and controls for power and process

BAILEY METER COMPANY

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In Canada—Bailey Meter Company Limited, Montreal

BAILEY METERS

CIRCLE 61 ON READER-SERVICE CARD

Veeder-Root READOUT Bulletin

One of a Series

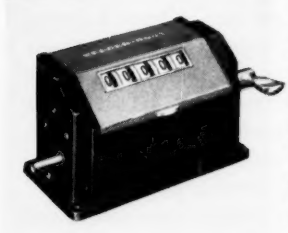
Predetermining Counters provide simplified methods for Automatic Control

Veeder-Root Predetermining Counters now make it possible to design and build automatic control into equipment of all types. They are available for mechanical, electrical and electronic control and offer many features and options to give your equipment extra value and versatility.

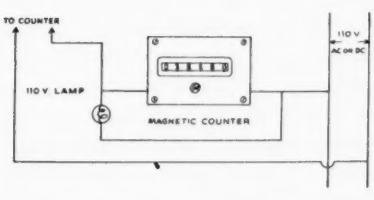
Predetermining Mechanical Counters can be applied to rotary, eccentric or stroke type motion, registering or counting whatever units are required — such as revolutions, motions, turns, pieces, lengths, and strokes. The newer electric and electronic Predetermining Counters use a special high speed light source and photo cell for non-contact counting on any machine or process.

Automatic control is provided by the predetermining counter actuating such devices as: lights, bells, signals and stop motions. They work at speeds up to 8000 counts per minute, can be easily incorporated into machine design and control panels. Application assistance is available from a Veeder-Root Counting Engineer; and specialized designs and modifications can be supplied in most cases. For complete information, call or write your nearest Veeder-Root office.

High Speed, Quick Reset Predetermining Counters for electrical and mechanical control, at speeds to 8000 cpm.



This counter has one set of wheels which are preset to any figure within the capacity of the counter by depressing the reset lever, raising the cover, and turning. The counter subtracts from the preset number to "00000", when a knock-off lever actuates an electrical switch. To reset, just press the reset lever, and counter returns instantly to preset figure. For Mechanical Control, counter actuates a mechanical lever instead of electrical switch. Speeds: 6000 rpm or 8000 counts per minute.



Addition of Magnetic Counter Provides Record of Total Lots.

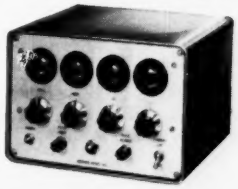
A Veeder-Root Magnetic Counter connected in series with the alarm or stop motion registers one unit for each of the predetermined lots produced. Provides a simple means to obtain both machine control and production control.

The High Speed Predetermining Counter is the basic counter in this complete line. It provides automatic control by this simplified method: . . . to set a run of 5451 pieces on the counter: (1) Set all white wheels to zero with one turn of wing-nut; (2) Now, set the metal wheels, one by one. Set first wheel to "5", opposite zero on its "opposite number" white wheel, then set the "4", "5" and "1" and that's all . . . you're ready to throw the switch and start the run.

Electric Predetermining Counter Ideal for Batching, Length Measurement and Materials Handling.

This new counter offers automatic reset plus other important features: **1.** Instant automatic reset . . . *Control* contacts operate and hold for 0.3 seconds . . . or for 2 seconds . . . or indefinitely. **2.** Counter can be modified for automatic sequential predetermining, using two or more preset numbers. **3.** A batch or totalizing counter can be added. This counter is adaptable to material handling applications, slow speed batch counting, length measurement, slitting, and similar applications. Speeds up to 1000 cpm.

High Speed Electronic Predetermining Counters Feature Automatic Reset, 5000 cps.



The No. 1604 features instantaneous recycling. Up to six decade counters, with one, two, or more sets of preset numbers . . . with or without photohead or enclosure. Output relay provides momentary or indefinite holding time. Batch totalizing available. Ideal for all high speed counting, up to 5000 cps, recycle at 1000 cps.

Send for Literature and Technical Data . . . Extensive information and specifications on how to use Veeder-Root Predetermining Counters are yours for the asking. Send today.

Veeder-Root

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CIRCLE 62 ON READER-SERVICE CARD

Temperature Measurement with

POST-WAR ADVANCES in solid-state physics in Europe and the U. S. A. have given us thermally sensitive resistors, or "thermistors," which can maintain their electrical characteristics for years—without significant drift even after continuous recycling of temperatures over spans of 400°F. It is now possible to purchase standard off-the-shelf thermistor thermometers for most industrial and research applications, eliminating "do-it-yourself" approaches with problems of thermistor stabilization, self-heating, dissipation constant, temperature coefficient, temperature-resistance curves, linearity of output, and replacement parts.

Thermistor Advantages

Thermistors offer two major advantages—(1) high sensitivity and (2) very small size of thermistor beads, which results in both low heat capacity and fast response and also permits the sensing-bead thermistor to be placed in intimate contact with, for example, a surface being measured. This sensitivity has permitted the construction of multiple-range instruments with very short spans on each scale.

Another advantage can be obtained by using high-resistance thermistor probes with relatively large resistance changes per degree of temperature. Such probes can be used with varying lead lengths, with relays, or even with slip rings in the probe lead circuits, without recalibration of the standard probes and instruments. This is possible because the resistance of even the slip rings is insignificant when compared with the 500,000 ohms resistance of many of the sensing elements available.

Thermistor thermometers can be made which are at their best in the medium temperatures where thermocouples are often inadequate. Even ISA "special limits of error" permit ±2 F° tolerances in the medium ranges, and to this must be added lead error and indicating instrument error when using thermocouples. Above 500°F, where thermistors are less adequate, thermocouples generate sufficient emf for accurate measurement.

Thermistor thermometers avoid reference-junction compensation difficulties, polarity checks, and lead-length compensations. Thermistor thermometers do require a battery or a-c power source, but drain on batteries is slight in most of the instruments because high-resistance bridge circuits are used. In such instruments, the battery life is shelf life.

Applications

The first uses of thermistors in heat measurement were primarily in medicine, chemical research (boiling points, melting points, heats of reaction), and many difficult research problems in heat transfer, including meteorology, cryogenics, and ultrasonic interferometry.

More recently, however, development, quality control, industrial instrumentation, and maintenance engineers have found the compact, portable thermistor thermometers ideal for checking in-place instrumentation; quickly inspecting parts on production lines; reading temperatures of chemicals, stored food, water, refrigeration systems, heating systems, etc.

Many applications are in the difficult field of surface-temperature measurement. Fig. 2 shows probes for special applications. Upper probe has needle tip and spring-mounted adjustable stop to allow insertion to the desired depth into rubber, plastics, etc. Lower left probe can be lowered into chemicals, water, etc. to determine stratified temperatures; leads can be thousands of feet in length. Lower right probe can be installed through the wall of an autoclave or drum. All probes are interchangeable and multiple range.

Using wet and dry sensing thermistors, unusual relative humidity accuracies are possible with a new small portable device (Fig. 3). The low heat capacity of the 0.014″-diameter thermistors yields rapid response and permits readings when only a small quantity of air is available for measurement as, for example, inside small closed ductwork and constant environmental chambers. Both wet and dry bulb temperatures can be read to within fractions of a degree in a total elapsed time of 10 seconds.

Thermistors as manufactured must be treated and aged to achieve temperature-resistance stability, and must be selected, ground off, or otherwise compensated to achieve interchangeability. In the U. S. A. selection

Thermistors

ROBERT M. ATKINS
President
Atkins Technical Inc.

and treatment seems to be preferred; European practice is to use measured compensating or "padding" resistors in series and parallel with the thermistor to achieve interchangeability and to improve linearity. The "Thermophil" thermistor instruments recently introduced in this country use thermistors stabilized by a novel high-frequency process. A popular thermistor used by this manufacturer has a resistance of approximately 770K ohms at 10°C, 175K ohms at 50°C, and 45K ohms at 100°C. After compensation with series and parallel resistors, however, the resistance-temperature relationship is almost linear, and ranges from 550K ohms to 200K ohms over the same temperature span. (Note: thermistors normally have a negative temperature coefficient.)

Thermistors can provide readout signals many times greater than platinum or nickel resistance bulbs, or than even the most sensitive thermocouples. Resistance changes of several thousand ohms per Centigrade degree are not unusual. Hence instruments can be built with extreme accuracies and short spans, measuring hundredths or even thousandths of a degree. Using special semiconducting materials, researchers have constructed thermistor thermometers for readings of various ranges approaching absolute zero or as high as 1100°C. For most industrial applications, however, thermistor sensitivity is used to give more widely required accuracies (within 0.2% to 0.7% of total span in some cases) with several overlapping scales and with more rugged and convenient direct indicating meters for service in temperature ranges between −150°F and plus 550°F.

Probe Selection

Proper selection of probe is essential, particularly for surface temperature. The instruments shown can be supplied with any of more than 100 interchangeable probes, each designed for various specific applications. Glass probes are preferred for reading in corrosive materials, for surface readings on electrically charged conductors (up to 380 v), or for the most accurate readings on surfaces of materials that are poor conductors of heat (painted surfaces, glass, etc). A metal probe on a poor heat-conducting surface tends to trans-

FIG. 1. BATTERY-POWERED instrument, covering 32 to 410°F on three overlapping scales, with silver-capped stainless-steel probe for surface-temperature measurements.

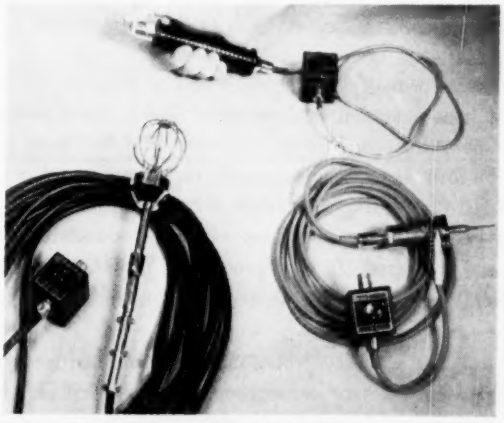


FIG. 2. PROBES FOR SPECIAL applications include needle tip for insertion to depth (top), tip for stratified temperature (left), thru-wall tip (right).

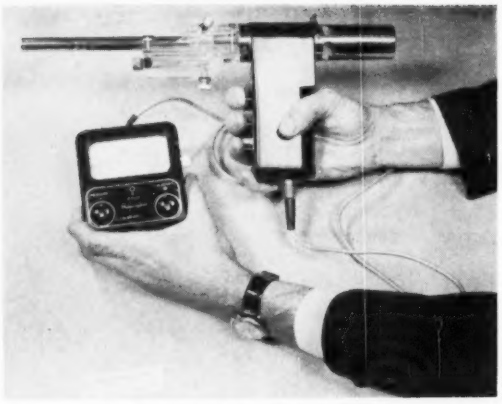


FIG. 3. **RELATIVE-HUMIDITY** indicator utilizing wet and dry thermistors.

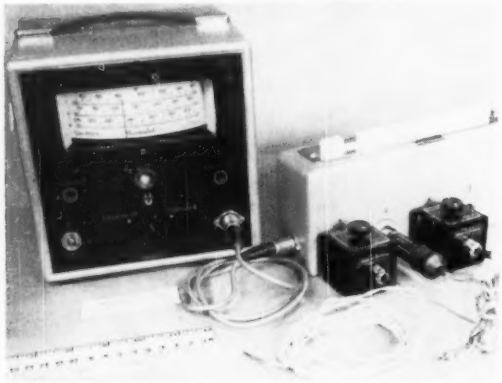


FIG. 4. **AC-POWERED** "Thermophil" electronic thermometer for continuous readout and optional recording. Multiple probes can be connected through switchbox.

fer heat from or to the measured spot through the probe shank faster than the measured materials can stabilize the heat balance. Industrial users may choose to ignore this small error in absolute accuracy, however, and use the repeatability of the metal probes for normal work to avoid broken glass tips.

Metal probes should have a cap of material which conducts heat well, such as silver, and a probe shank of poor heat-conducting material. Stainless steel in tube form is widely used. Such metal probes are preferred for reading surface temperatures of metals, and in many other applications where the durability of metal is desired. In food processing, for example, the metal tips are popular to replace glass thermometers for safety reasons.

For best accuracy probes must be calibrated for use either for surface measurements or for immersed readings, not both. The surface-measuring probe is calibrated to transfer heat at the tip face only, while losing or gaining heat along the shank of the probe to the air or other medium. If such a surface-calibrated probe is used immersed in a heated liquid or plastic material, the resulting readings will be slightly high (approximately 10 C° at 60°C). Conversely, probes calibrated for immersed readings, if used on surfaces, will indicate low on heated surfaces and high on cold surfaces.

The size of a surface-temperature-sensing element also is important. It should be as small as possible to avoid interfering with radiant heat transfer of the surface. Flat sensing elements cemented or even taped to surfaces are subject to such errors. Ideally, a small thermistor probe can be mounted in a small hole drilled from the back almost to the surface to be measured; probe leads then can be brought out through connectors or slip rings to the indicating instrument.

After suitable calibration of each probe (by manufacturer or by user), multiple-probe installations of both surface and immersed reading probes can be used through switch boxes, etc., to a single readout instrument (Fig. 4).

Surface-Temperature Technique

When using any standard heat-sensing elements, the calibrating conditions must be duplicated or compensated for in the application. "Thermophil" surface probes are calibrated on metal surfaces of carefully controlled temperatures, in still air, with the probe held vertically against the measured surface with a pressure of 1 to 1½ pounds. This pressure has been found to assure an adequate heat flow for the temperature ranges involved. Users of surface probes usually touch the probe lightly to the surface to be measured and take a tentative reading, then increase pressure on the probe until further pressure does not cause a higher reading. For users who desire exactly the same pressure on each measurement, spring-mounted probes can be supplied which maintain the probe against the measured surface at the required pressure. The spring also serves as a shock absorber for rugged use by unskilled personnel.

Future Developments

An increasing number of original equipment manufacturers are expected to incorporate short-span thermistor thermometers in equipment such as heat-sealing devices, paint drying ovens, constant-temperature cabinets, etc. Such acceptance awaits recognition of recent thermistor stabilization advances.

It is hoped that in the future even improved stability over even wider temperature spans can be achieved by reducing hysteresis effect. The high accuracies of stabilized thermistor sensing elements indicate some industrial applications with the more accurate digital readout devices. Almost certainly the intensive research now underway throughout the world on semiconductors and thermoelectric power elements will lead to new heat-sensing devices.

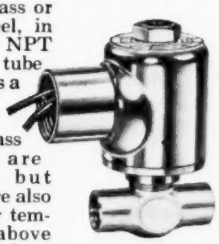
HOKE Flow Sheet [1]

HOKE REPORTS ON FLUID CONTROL

A VALVE NAMED "DESIRE"

With apologies to Tennessee Williams, we really have produced a Solenoid Valve line based on *your* desires. We surveyed all the solenoid valve users we could find to determine what *you* wanted. The result is Hoke's "User Designed" Series 90 and 95, two-way and three-way, direct-acting solenoid valve line.

Thanks to you, we have much to brag about. Here's what we have been saying about these new valves: lightest weight – smallest size – no-hum operation – lowest temperature rise – lowest power consumption – stainless steel plunger – silver AC shading coils – easiest installation – packless construction – 360° rotatable housing – operates in any position.



We make them of forged brass or stainless steel, in ⅛" and ¼" NPT size or JIC tube ends. There's a variety of AC and DC voltages. Class "A" coils are standard, but Class "H" are also available for temperatures above 212°F. For those with high insurance rates, we can supply explosion proof coil housings.

Now that we've bragged a bit, we must also apologize for our premature enthusiasm. We were so excited about this product that we stirred up a hornet's nest of interest before we were ready to deliver in quantity. Shipments were slow at the start, but now we can have any reasonable quantity of these "desirable" solenoid valves "on-stream" in your plant when you want them.

There's only one way to get conclusive performance proof – buy a valve. Ask for Bulletin SV-1159.

What Goes With What?

This is a question engineers and chemists are constantly asking each other. Not that we want to do away with this healthy interplay at the water cooler, but we have put together a slide rule that answers all these questions. It lists 22 metals and materials and their degree of resistance to 247 corrosive agents.

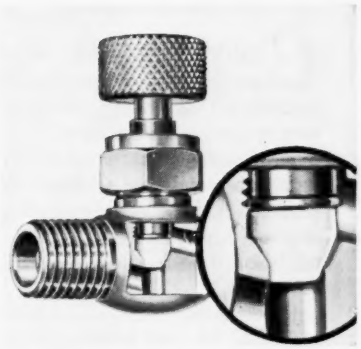
Got yours? Write now while there are a few (thousand) left.

HOKE'S NEW PLASTIC STEM TIPS END CHRONIC FAILURE PROBLEM

Galling and scoring valve seats plagued valve users and manufacturers for years, until somebody thought of using plastic stem points. This idea worked well at low pressures, but when the pressure increased – poof! – the valve blew its tip. Up to now, this problem had continued to bother valve makers.

Fortunately, a die-hard Hoke engineer insisted he could put a permanent plastic tip on a high pressure valve. We gave him his head and he gave us a plastic-tipped valve-stem (using either Kel-F or Nylon). His unique design incorporates a crimped metal shell that grabs the plastic tip and *really* holds!

Not satisfied with this monumental accomplishment, he proceeded to tackle leak problems at the stem packing. He put an O-ring seal on the stem and compressed it with a newly-designed Nylon collar. The collar serves a dual role, for it also prevents grit and other foreign matter from chewing up the O-ring. Valves of this new design have performed successfully up to 3500 psi. Our die-hard engineer not only

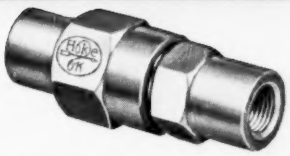


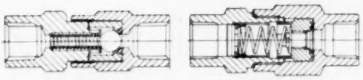
ended galling, but also seat leakage, stem leakage and wear problems – all at one swoop.

There's only one feature about this new development that worries us–since we do not expect replacements we may have designed ourselves right out of the valve business! We make these little dandies of either forged brass, bar stock or 316 Stainless, with ⅛" and ¼" male connections. Temperature limit is 400°F. For the complete story, write, wire, phone or we'll come see you.

Hoke "TECH-SPEC"

570 SERIES CHECK VALVES





BALL TYPE PISTON TYPE

Designed for gas or liquid service at pressures to 5000 psi. Ball and piston types for extremely effective leak-tight closure, coupled with minimum flow resistance. Ball types in ⅛" and ¼" sizes; piston types in ⅜" and ½" sizes. Temperature limits, –40 to 200°F. Body materials are Brass or 303SS. End construction is interchangeable with any combination of inlet and outlet connections. O-ring seals are available.

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- ☐ Solenoid Valves
- ☐ 570 Series Check Valves
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CIRCLE 63 ON READER-SERVICE CARD

Low-Temperature Characteristics of Chromel-Alumel Thermocouples

JOHN F. CARLSON, Hoskins Manufacturing Co.

CHROMEL-ALUMEL thermocouple* alloys are accepted for measuring high temperatures (up to 2300°F) accurately, but their use for low-temperature measurement has been based more on an assumption of accuracy than on factual data. These special tests were conducted to determine the actual low-temperature emf characteristics of present standard-grade Chromel-Alumel wires as compared with the values established for these alloys by the National Bureau of Standards.**

Representative samples of Chromel and Alumel wire in 8-, 14-, 24-, and 26-gauge sizes were selected at random from standard stock material drawn from different production melts. Wires taken from each melt and a known platinum standard were than welded together at one end to form a 9-wire thermocouple assembly having a single common hot-junction. Each thermocouple assembly was inserted in a drilled-out copper block together with a calibrated platinum resistance thermometer to measure actual temperatures during the experiments. The entire unit was then placed in a large vacuum bottle and connected as shown in Fig. 1.

The copper block containing the test unit was first immersed in methanol, and dry ice was added to cool the liquid from room temperature down to —109°F. During cooling, temperature-emf readings were taken on each wire against the platinum standard and the resistance thermometer—after first allowing the test apparatus to reach an equilibrium temperature at each check point. Liquid N_2 was used for obtaining lower temperatures to —320°F.

In addition to checking the thermocouple assemblies at various points during this cooling process, temperature-emf readings were taken as the test units returned to room temperature. This required time because temperature rose on the order of 4°F per hour, but it checked the cooling equilibrium-temperature readings.

Results

The readings (Table 1) indicate good agreement between the actual low-temperature emf characteristics of present standard-grade Chromel-Alumel thermocouple wires and the values established for these alloys by the National Bureau of Standards in 1934.

*The words "Chromel" and "Alumel" are registered trade names of Hoskins Manufacturing Co., Detroit.

**National Bureau of Standards' Research Paper R.P.-787 and NBS Circulars 508 and 561.

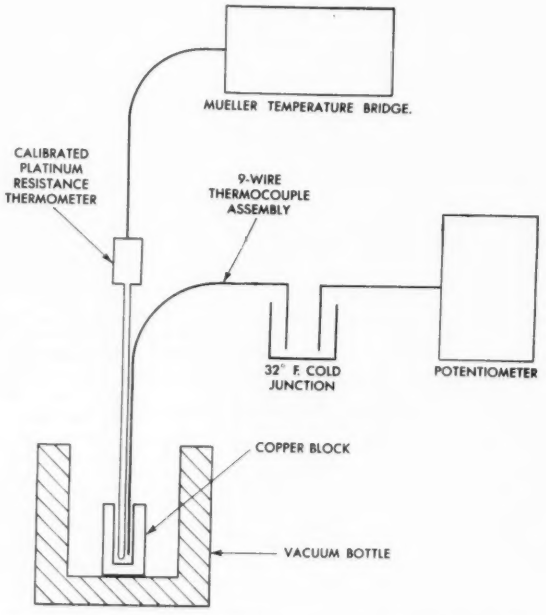


FIG. 1. TEST APPARATUS used to determine actual temperature-emf characteristics of Chromel-Alumel thermocouple wires at temperatures down to —195.6°C (—320°F).

Table 1—Thermal EMF of Chromel-Alumel Thermocouple Alloys At Low Temperatures. Reference Junction at 32°F.

Temperature (°F)	EMF (mv)	
	NBS Values*	Actual Values**
+ 15	—0.37	—0.39
— 51	—1.72	—1.75
— 67	—2.03	—2.05
— 76	—2.20	—2.24
— 87	—2.41	—2.44
— 93	—2.52	—2.55
—109	—2.82	—2.83
—146	—3.46	—3.45
—196	—4.24	—4.23
—203	—4.32	—4.33
—227	—4.67	—4.68
—259	—5.07	—5.05
—307	—5.57	—5.59
—320	—	—5.71

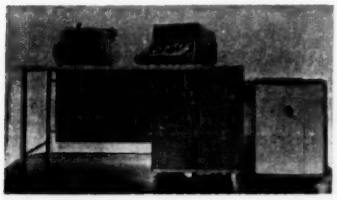
*As published in NBS Circular #508
**Data shown are average emf readings obtained from four thermocouples made of 8-, 14-, 24-, and 26-gauge wires joined together to form a common hot junction.

A state-of-the-art survey, giving the features of all available digital control computers and their announced applications to date.

Control Computers

Autonetics

Autonetics Division of North American Aviation, Inc. offers the Recomp general-purpose digital computer (Fig. 1) that uses a disc memory of 4096 word capacity, has solid-state circuitry, accepts 49 instructions, provides 0.52 millisec add time and 10.4 millisec multiplication time (without access).



Process Application	Variables Scanned or Logged	Operating Guides Computed	Variables under Computer Control
Phillips Chemical Co., Sweeny, Tex.—natural gas liquids cracking furnace.	Yes	Furnace conditions and yields.	No

Bailey

The Bailey Meter Co. system of on-line digital computer control (Fig. 2) uses primary measurements by standard Bailey Transducers which are collected and processed by units of the solid-state Bailey Metrotype System. Computing functions as required are accomplished by adding unit-function solid-state, plug-in modules to the Metrotype system. Memory can be magnetic drum or magnetic core, as desired.

Process Application	Variables Scanned or Logged	Operating Guides Computed	Variables under Computer Control
Union Carbide Nuclear Co., Paducah, Ky.	Yes	Every five minutes predicts total power demand for ½-hr periods over 17 circuits	No

Fig. 2.

Bendix

The Bendix G-15 (Fig. 3) is a general-purpose computer of medium speed, with DDA accessories. Internal circuitry uses serial logic and time sharing techniques. Basic equipment includes typewriter for input, output and control, and photoelectric paper tape reader and tape punch. Output is adaptable to control application.

Memory is magnetic drum; circuitry uses premium grade commercial computer tubes. Number of instructions—basic commands, 50; micro-coding, 1300; interpreter method, 52. Add time—0.54 milliseconds, single-precision; 0.81 milliseconds, double-precision; multiply time—2.43 to 16.7 milliseconds, single-precision; 2.43 to 33.1 milliseconds, double-precision.

Fig. 3.

Unique features include special input/output panel with 6 plugs for multiple connection of digital on-line devices. Separate computer commands provide control of information into and out of each plug. "Only computer in its class which (1) has buffered input/output permitting simultaneous computation with input or output operations, (2) includes a high-speed photoreader as standard equipment."

Process Application	Variables Scanned or Logged	Operating Guides Computed	Variables under Computer Control
Cornell Aeronautical Laboratory, Ithaca, N. Y.	Air traffic control of carrier landings of jet and propeller driven aircraft.		
MIT Wind Tunnel	Six-component, strain-gage balance, force, and moment data	Body, stability or wind axes coefficients referred to aerodynamic angles of attack and yaw	No
Textile Thread Tests	Strain gage measurements of thread characteristics	Classified	No

Daystrom

Daystrom's Control Systems Division provides a completely solid-state digital computer system (Fig. 4) capable of handling many hundreds of inputs—analog, digital, contact closures, etc. Outputs for control purposes and information devices are unlimited in number. Magnetic core memory is provided. 46 instruction commands can be used with or without address modification. Add time is 1.32 millisecond, multiplication time is 10.32 milliseconds including memory lookup.

Features include highly developed peripheral equipment; A-to-D and D-to-A conversion, random-access

Fig. 4.

switching, digital information acceptance, pulse count inputs, fast single-command square-root extraction, integral program interrupt, elimination of plug-in connectors, and non-interruption of computation or print out.

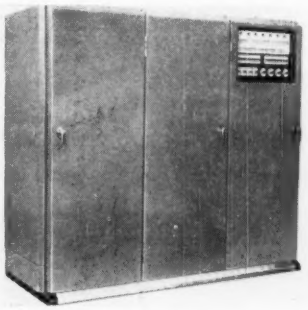
Process Application	Variables Scanned or Logged	Operating Guides Computed	Variables under Computer Control
Louisiana Power and Light, Sterlington, La.	350 analog and digital	over-all efficiency	Two major control loops; more planned
Lousiana Power and Light, Little Gypsy Station, LaPlace, La.	850	Component and over-all efficiencies	Combustion, steam temp., feed water. Control will (1) seek maximum efficiency, (2) maintain load during plant equipment failure, and (3) start up and shut down units.
Gulf State Utilities, Willow Glen Station, St. Gabriel, La.	320	Planned	No
Universal Oil Products, Des Plaines, Ill.	Experimental process control	unit for process	2-32 variables
Carolina Power and Light, Darlington, Sta., N. C.	444	Coal-fired boiler efficiency, turbine efficiency, performance of condenser, heaters, etc.	Planned
Kansas City Gas and Electric, Gordon Evans Station, Wichita, Kansas	444	Gas-fired boiler efficiency, turbine efficiency, cooling tower performance	Planned
Great Lakes Steel Co., Div. Nat'l Steel	Complete integrated control of high-speed hot-strip mill. Starting with billet composition data, computer will supervise oven heating, set rolls and presses, control speeds, etc., for simultaneous multi-billet rolling.		

Ferranti

The Ferranti Argus digital computer (Fig. 5) is solid state on printed circuitry with core memory.

Basic computers hold 1024 instructions and 1024 numbers in store. This can be extended to 4096 instructions, or 2048 numbers. Input/output information can be analog and parallel. Multiplication—135 to 270 microseconds.

Fig. 5.



Foxboro-RCA

Foxboro computing control systems will use the RCA 110 digital control computer (Fig. 6). The 110 uses a random-access magnetic core memory (256 to 4096 words) for working storage; bulk storage (4096 to 40,000 words) is magnetic drum. It can handle both decimal and binary numbers internally. Priority

Fig. 6.

assures that no program can interrupt one of greater importance. All-transistor digital modules are used throughout, with diagnostic routines for automatic, on-line self-checking and alarm.

Inputs (unlimited number) and outputs can be analog, binary or decimal. Add speed is 0.27 millisecond; multiply speed is 3.51 milliseconds.

General Electric

General Electric's 312 transistorized digital control computer (Fig. 7) is a general-purpose stored-program computer with magnetic drum memory. Basic memory is 2,048 words to 16,384 words with optional fast access through trailing heads. More than 60 commands include special instructions for process applications. Automatic instruction modification is included. Add speed is 0.192 or 0.288 millisecond; multiply time

Fig. 7.

is from 0.288 to 2.016 millisecond. "Ten 312 systems have been sold for industrial and utility applications. Four of these have control features."

Process Application	Variables Scanned or Logged	Operating Guides Computed	Variables under Computer Control
Jones & Laughlin Steel Co., Aliquippa, Penna.	Yes	Yes	Yes
Southern Calif. Edison, Huntington Beach Station	Yes	Yes	Yes
Bethlehem Steel Plant, Buffalo, N. Y.	Yes	Yes	No
"A Midwest" Steel Co.	Yes	Yes	Yes
An Eastern Steel Co.	Yes	Yes	No
Public Service of Oklahoma	Yes	Yes	No
2-312's for a Utility Co.	Yes	Yes	No
GE-ASD Schenectady, N. Y.	Yes	Yes	Yes

Genesys

Genesys digital control computer uses a *memory disc* (Fig. 8) and hybrid operation combining incremental (DDA) and general-purpose computer techniques. Memory comprises 10,000 words of 20 bits each. About 4/5 of memory is used for g-p computing; 1/5 for incremental functions. Optional back-up memory can supply 1.5 million words additional memory.

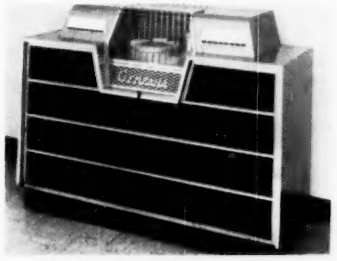


Fig. 8.

Instructions—64 to 250, single-address form. Clock frequency is 200 kc. Add time—several ms. Incremental unit comprises 250 integrators and multiplier units. Logging and control outputs are available.

Process Applications	Variables Scanned or Logged	Operating Guides Computed	Variables under Computer Control
Sun Oil Co., Marcus Hook, Pa.	Yes	Yes	No

Information Systems, Inc.

Information Systems, Inc. offers a digital control computer with a special high-speed 12-bit fast arithmetic unit (Fig. 9). Only 2.8 milliseconds are required to compute and store any multiplication, division, analog-to-digital conversion, or square root, to an accuracy of 1 part in 4096. This is in addition to the 39-bit arithmetic unit in the main computer channel (requiring 28 milliseconds per multiplication).

All logic elements are solid-state components (core-transistor) for both memory and control systems. Add time is 0.72 millisecond, including read and write functions and the fast multiply time of 2.80 milliseconds also includes read and write time. Rapid-access bulk memory has 4096 words (160,000 bits), and is ferrite core with random access. A secondary memory is magnetic film with up to 130,000 words per 1000′ reel.

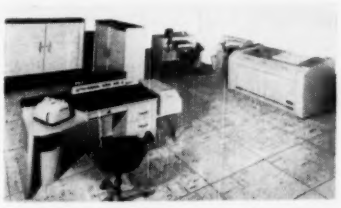


Fig. 9.

Process Applications	Variables Logged	Operating Guides Computed	Variables under Computer Control
Gulf States Utilities Co. Lake Charles, La.	110	30	16
DuPont, Beaumont, Texas	250	30	No
DuPont, Beaumont, Texas	350 maximum	Unknown	Unknown
DuPont, Florence, S. C.	450	Unknown	Unknown
Westinghouse Elec. Corp. Cheswick, Pennsylvania	256	Various	10

L&N/Philco

Leeds & Northrup computer control systems will use the LN 3000 digital computer. Circuitry is solid state.

Process Application	Variables Scanned or Logged	Operating Guides Computed	Variables under Computer Control
Public Service Electric & Gas, Bergen Station	600	Trend	No
Fla. Power and Light Co.		Yes	Regulates 94% of generation, including nine stations
Esso Standard Oil Co. Baton Rouge Refinery	160	27 performance criteria for catalytic cracker	No
Carolina Power & Light		Line losses	Regulates 90% of generation including 5 stations, 14 units.

Librascope

Librascope, Inc., a subsidiary of General Precision Equipment Corp., offers the Libratrol 500 (Fig. 11), a

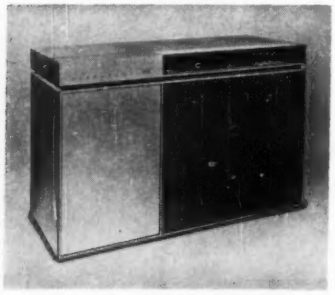


Fig. 11.

general-purpose digital control computer. Memory is magnetic drum with 4096-word capacity plus a 64-word revolver for input-output. Number of different instructions—20. Add time is 250 microseconds: multiply time is 15 ms. Basic console includes complete scanning, digitizing and real-time control capabilities.

Process Application	Variables Scanned or Logged	Operating Guides Computed	Variables under Computer Control
Public Service Co., of Colorado	72 channels, 55 telemeters.	Gas load distribution	No

Minneapolis-Honeywell

Minneapolis-Honeywell's Datamatic Division offers an all-transistor Model D-290 digital computer. Memory is magnetic drum and core. No. of instructions—about 60 (variable). Add time—0.14 millisecond. Multiply time—0.8 millisecond.

Process Application	Variables Scanned or Logged	Operating Guides Computed	Variables Under Computer Control
Philadelphia Electric Co., Phila., Pa.	In excess of 4,000	Yes	Yes

Royal McBee

Royal McBee markets the Royal Precision LGP-30, a desk-size, general-purpose digital computer (Fig. 13). Program is stored; 4096 memory locations can

Fig. 13.

be used to store either data or instructions. Complicated calculations can be made in ⅓ second. Equipment can perform calculations with thousands of input variables, or more complex calculations with fewer variables.

Computer includes 113 tubes, 1450 diodes. Memory is magnetic drum.

Process Application	Variables Scanned or Logged	Operating Guides Computed	Variables under Computer Control
Standard Oil of N. J., Baton Rouge, La.	Yes	Yes	No
Standard Oil of N. J. (pilot plant in conjunction with CEC), Linden, N. J.	160	27	No
West Penn Power Greensburg, Pa.	Solves load flows in network up to 100 loggers and 270 lines	Yes	No

Thompson-Ramo-Wooldridge

The Thompson-Ramo-Wooldridge Products Co., a division of Thompson Ramo Wooldridge Inc., offers the RW-300 digital control computer (Fig. 14). Basic commands are 20; distinct commands, more than 160.

Fig. 14.

Memory is magnetic drum with 7,936-word capacity. Fast-access circulating register holds 16 words; non-erasable loading program holds 128 words. Add or subtract time is 0.91 ms, multiply time is 2.99 ms, divide time is 3.12 ms.

Process Application	Variables Scanned or Logged	Operating Guides Computed	Variables under Computer Control
Texaco, Port Arthur, Texas			Catalytic polymerization unit control.
Riverside Cement Oro Grande, Calif.			Blending and storing raw materials Planned
Goodrich Chemical Co., Calvert City, Ky.			Vinyl chloride monomer unit control.
Monsanto Chemical Luling, La.			Chemical process unit control.
Union Carbide Chemical, S. Charleston, W. Va.			Pilot plant control.
Electricite de France Chinon, France			Nuclear reactor monitor.
Douglas Aircraft Santa Monica, Calif.			Production testing of components

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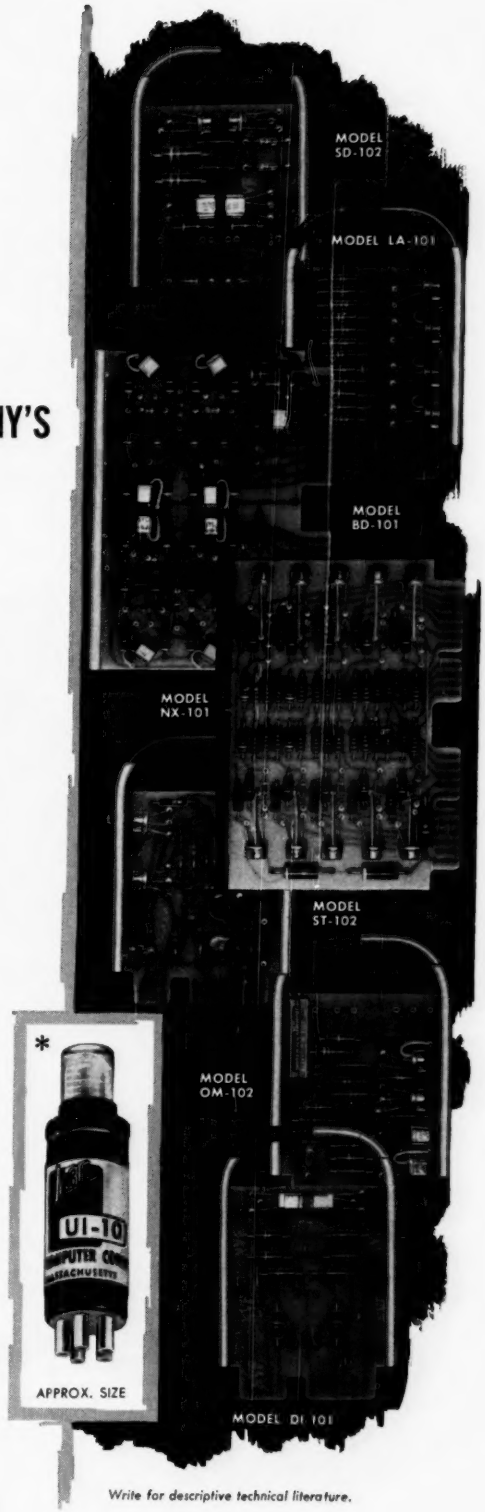

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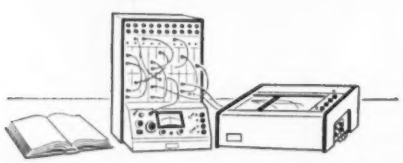

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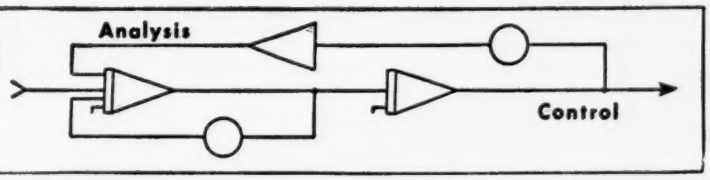

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Bits

This month our report is devoted almost exclusively to the July meeting of the Western Simulation Council at the Beckman/Berkeley Computation Center in Los Angeles. Subject was "Techniques for Accuracy Improvement of Analog Computer Solutions." *Bill Kindle's* "Accuracy Considerations in Using Servos" is reported in full, and an abstract of *Shozo Matsuno's* discussion is presented.

Pieces

MEETING OF WESTERN S/C OF 30 JULY ON "IMPROVING COMPUTER SOLUTIONS"

Approximately 43 representatives of 23 organizations gathered at the Beckman/Berkeley Computation center in Los Angeles on 30 July to discuss "Techniques for Accuracy Improvement of Analog Solutions."

Irwin Pfeffer (Space Technology Laboratories, Los Angeles 45, Calif.), Chairman of the Western Simulation Council, presided, and *Bill Kindle* of EAI Computation Center (El Segundo, Calif.) was the first speaker. Your Editor was unable to attend this meeting, so we will give you Bill's notes just as he gave them to us rather than Bill's talk just as he delivered it.

Kindle on "Accuracy Considerations in Using Servos"

Servos are used to introduce non-linear operations into the mechanization of equations on the analog computer. The circuits which are constructed to perform these non-linear operations are not unique, and careful choice of the form of such circuits can do much to enhance the accuracy of computer solutions.

A general philosophy for aiming toward optimum use of servo components may be derived from the following statement:

In non-linear problems which have sensible* linearizations, servos should be used to introduce the *variations* in the coefficients of the problem and should not be required to pass the *linear* portion of the signal through their electro-mechanical drive.

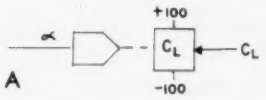
The further a problem deviates from having a sensible linearization** the less obvious becomes the application of this criterion. There are, however, many significant situations where it can be readily applied. Some examples follow:

*Do you mean, Bill, that you can sense them or that they make sense? Or both? —JM

**The sillier you are to try to linearize it!?

Example 1—Aerodynamics

In generating an aerodynamic coefficient such as, for example, the lift coefficient of an airframe as a function of angle of attack. Consider the methods in Figures 1 and 2.



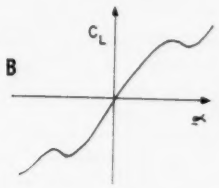


FIG. 1

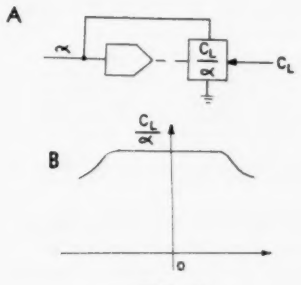


FIG. 2

In method 1 the servo must pass both the linear and non-linear variation of C_L with α.

In method 2 the linear variation of C_L with a passes through the tapped-pot function generator as a voltage and can thus carry high frequencies. Only the non-linear variation of C_L with a is introduced by the servo.

This is illustrated in Figures 1a and 2a. The inherent physical properties of airframes, wherein large swings in angle of attack occur at low frequencies and high frequencies have small amplitudes, permit the servo simulation of the aerodynamics of airframes with natural frequencies higher than the natural frequency of the servo.

Figure 2a illustrates that for small values of a the value of C_L/a is independent of a. Thus, for high-frequency small variations in a the fact that the servo is unable to follow a introduces no error.

Also, for symmetrical airframes, C_L/a is symmetrical about the origin of a, and the function C_L/a can be generated as a function of $|a|$, which permits twice as many points in the function.

Another advantage of this technique is that it yields more accurate steady states for small values of a than can be achieved using electronic non-linear equipment. This added accuracy can be very important in computing induced drag, which accounts for the energy lost in drag due to lift.

Example 2—Pneumatics

In simulating the isothermal compression of a gas in a chamber

$$\frac{d}{dt} PV = RT \Sigma w$$

where P is the pressure; V is volume; R is gas constant; T is temperature, and Σw is the sum of weight flows in and out of the chamber.

This equation is normally solved for the pressure with the volume variation and weight flows of gas as inputs.

Consider the following two methods:

1. $P = (1/V) \int RT \Sigma w \, dt$

2. $P = \int \frac{1}{V} \left[RT \Sigma w - P \frac{dv}{dt} \right] dt$

as mechanized as shown in Figs. 3 and 4.

These equations are mathematically identical, and the obvious choice is method 1, which is simpler. However, method 2 is the proper choice.

By method 2 the high-frequency dynamics of the "pneumatic spring" are introduced by dv/dt, and the non-linearity of the "fluid spring" is introduced by the multiplication by P and the division by V.

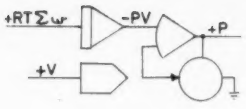


FIG. 3

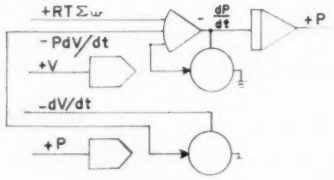


FIG. 4

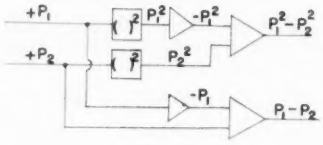


FIG. 5

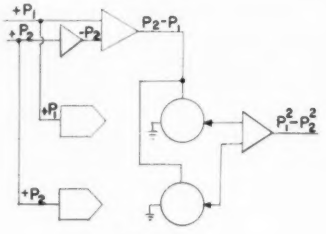


FIG. 6

By method 1 the V servo is required to pass the linear spring signal in addition to introducing the non-linear effects.

When the circuit of method 1 is closed with other circuits of a problem, it will yield spurious oscillations due to the lag introduced by the servo.

Of particular interest in the fact that experience has shown that electronic multipliers used in the circuit of method 1 will generate spurious oscillations for problems where servos used in the circuit of method 2 will not. Thus, the use of electronic components in place of servos does not relieve the analog computer user of his concern for utilization of his equipment for best dynamic accuracy.

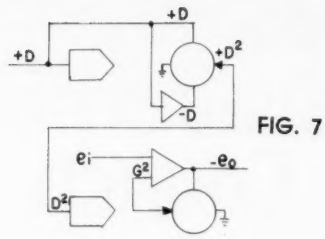


FIG. 7

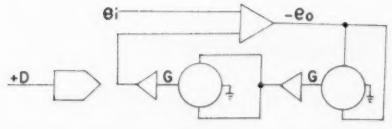


FIG. 8

Example 3—Hydraulics

In liquid fluid dynamics, flows often depend on the difference of squares of pressures, and forces may depend on pressure differences. Thus, the occasion arises where it is very important to have the pressure difference and the difference in the squares go to zero simultaneously to avoid spurious offsets.

This can be achieved by expanding the difference in the squares:

$$P_1^2 - P_2^2 = (P_1 + P_2)(P_1 - P_2)$$

Consider the methods of Figs. 5 and 6:

When $P_1 = P_2$, method 1 depends on the accuracy of the squaring devices to achieve a null in $P_1^2 - P_2^2$.

By method 2, a null in $P_1 - P_2$ assures a null in $P_1^2 - P_2^2$ regardless of errors introduced by the servos.

It is interesting to note that some of the advantages of this technique are sacrificed if the servo multipliers are replaced by electronic multipliers; this does not take advantage of the inherent property of servo multipliers to give an absolute zero output for zero input to the pot.

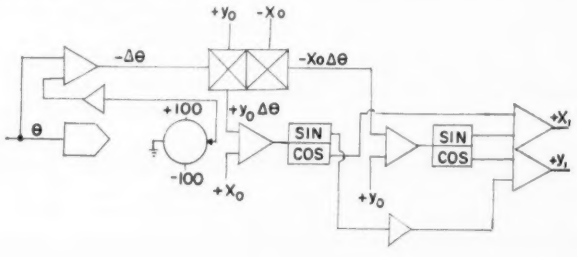
Example 4—High Q Resonance

In computing (algebraically) the amplitude versus frequency of a high Q circuit, an equation arises of the form:

$$e_o/e_i = 1/(1 + D^2)$$

where $-D_M < D < D_M$ and $D_M >> 1$. Good accuracy is required around $D = 0$.

FIG. 9



Consider the methods of Figs. 7 and 8:

Note 1: The "one" in $1 + D^2$ is provided by the normal amplifier feedback in both circuits.

Note 2: The G's denote gains necessary to allow $D > 1$.

Note 3: In circuit 2 the equality, $D^2 = D \mid D \mid$ is used to save amplifiers.

If the servo error for zero input is ϵ, then method 1 gives:

$$e_o/e_i = 1/(1 + D^2 + G^2\,\epsilon)$$

whereas method 2 gives

$$e_o/e_i = 1/[1 + (D + G\,\epsilon)^2]$$
$$= 1/(1 + D^2 + 2GD\,\epsilon + G^2\,\epsilon^2)$$

Thus the error for method 1 approaches $G^2\,\epsilon$ as D approaches zero, whereas the error for method 2 approaches $G^2\,\epsilon^2$. Since ϵ is of the order of 0.001, method 2 is about 1000 times better than method 1 around $D = 0$.

Although this technique is not restricted to servos, the stability of the circuit of method 2 is somewhat easier to achieve using servos than using electronic multipliers.

Example 5—Resolvers

In many applications, the lag of a servo resolver imposes severe limitations in analog simulation. The following discussion suggests a way of appreciably extending the frequency response characteristics of rectangular and polar resolvers by adding "tweeter" channels to the already existing "woofer" channels.

For a rectangular resolver,

$$x_1 = x_o \cos\theta + y_o \sin\theta$$
$$y_1 = -x_o \sin\theta + y_o \cos\theta$$

When the resolver lags such that the shaft position is θ_o instead of θ, and the error is defined as $\Delta\theta$, i.e. $=$

$$\theta \equiv \theta_o + \Delta\theta$$

Then for small $\Delta\theta$,

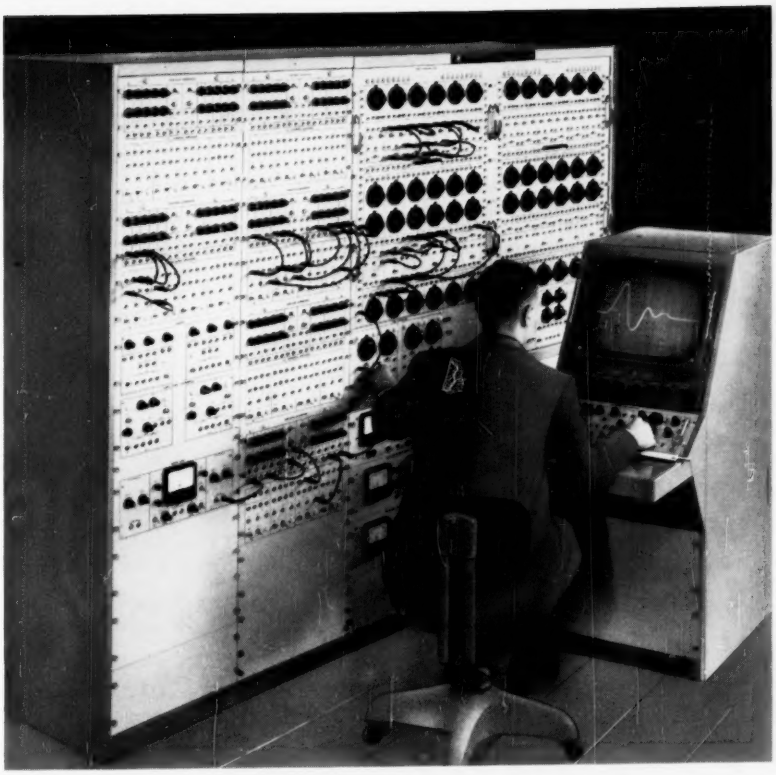
$$\sin\theta \approx \sin\theta_o + \Delta\theta\cos\theta_o$$
$$\cos\theta \approx \cos\theta_o - \Delta\theta\sin\theta_o$$

And the equations for the rotation of axes become

$$x_1 = (x_o + y_o\,\Delta\theta)\cos\theta_o + (y_o - x_o\,\Delta\theta)\sin\theta_o$$

$$y_1 = -(x_o + y_o\,\Delta\theta)\sin\theta_o + (y_o - x_o\,\Delta\theta)\cos\theta_o$$

By picking off $\Delta\theta$ from the difference between the servo input voltage and the follow-up pot voltage, and using an electronic multiplier, the correction terms for the "tweeter" channel are introduced as shown in Fig. 9.



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*An analysis of a missile miss-distance was conducted at the GPS COMPUTER CENTER by the research laboratory of a large aircraft firm. Their report stated that, "25 times as much data (with higher confidence-level) was collected in one week on the GPS computer as was collected and analyzed in 4 months time on a slow-speed computer."

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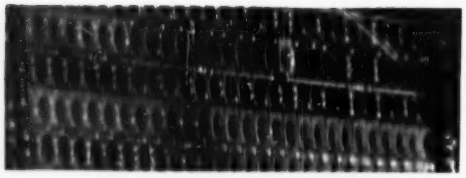

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9. It is the only computer offering card-programmed diode function generators.

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12. Lowest amplifier grid-current $< 10^{-9}$ ampere.

13. Stable amplifier operation over the entire feedback range from zero to infinity.

14. Drift < 50 μv in 8 hours in summing mode.

15. Amplifier frequency response—flat to 10,000 cps and only 3 db down at 28 kc.

16. Only diode function generators utilizing resistors, potentiometers, and diodes of equal quality to those in computing networks.

17. Only diode function generators with individual hi-lo gain positions for *each* segment.

18. Lowest function generator drift < 5 mv/8 hrs.

19. Highest servo multiplier accuracy, ±0.008%.

20. Only fully shielded patch *bay* and patchboard.

21. All contacts in patching system gold-plated.

22. Highest performance electronic multiplier—flat to 10,000 cps and only 3 db down at 20 kc.

23. Only servo multipliers and resolvers with zero backlash gearing—maximum one part in 36,000.

24. DC tachometer feedback on all servos.

25. Dynamic servo error—less than 50 mv at one cps.

26. Lowest step-function overshoot—less than 1%.

27. EVERY SPECIFICATION IS GUARANTEED TO BE TRUE PERFORMANCE STANDARD—IN SUSTAINED OPERATION.

28. Highest sin-cos resolver accuracy ±0.03% peak-to-peak.

29. Power supplies eliminated from console—lowest, most stable operating temperatures—rise < 3°C.

30. Passive networks stabilized at < 1°C above room ambient—no oven required.

31. Servo-set pots can be set to 2 parts in 10,000.

32. Accuracy of computing networks at least 0.01%.

33. Lowest computer cross-talk—rejection greater than 2,000 to 1.

The MC-5800 can be operated at LESS COST

34. Greatest available problem capacity per dollar—by 20%.

35. Least cost for future expansion.

36. Output tube filaments operate with DC bias for maximum life.

37. Centralized overload indication for quicker trouble-shooting.

38. Only computer with hermetically sealed transformers.

39. Choppers employ double-contacts in parallel for maximum life.

40. Plug-in relays and step switches throughout for least down time.

41. Plug-in dynamic components ease maintenance.

42. Quickest trouble-shooting by automatic problem check.

43. Costliest and best patching system for lowest programming cost thru maximum reliability of patchcord connections.

44. Choppers de-energized when computer in standby for max. life.

45. Separate power-supply venting minimizes room heat load.

46. Exclusive equipment-door packaging for free access and quick maintenance *without* shutdown.

47. Insulated patchboard prevents costly shorting accidents.

48. Sealed servo gear boxes for maximum reliability.

49. Fully transistorized ADRAC system with plug-in logic modules.

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The MC-5800 can SOLVE MORE OF YOUR PROBLEMS

51. Exclusive dynamic memory makes automatic iterative solution of statistical or optimization problems a reality.

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54. More computer capacity per dollar means more solutions.

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57. Add-on capacity up to 134 amplifiers, 30 electronic multipliers, 18 diode function generators, 2 time-delay generators, 8 relays with amplifiers, 4 bi-variable function generators, 6 servos, 8 function switches—all field-expandable without mechanical rework or rewiring.

58. Add-on features include automatic problem check, integrator rate test, high-speed repetitive operation, dynamic memory, expanded-time base, compressed-time base, servo-set potentiometers, and ADRAC (Automatic Digital Recording and Control) system—all field expandable without mechanical rework or rewiring.

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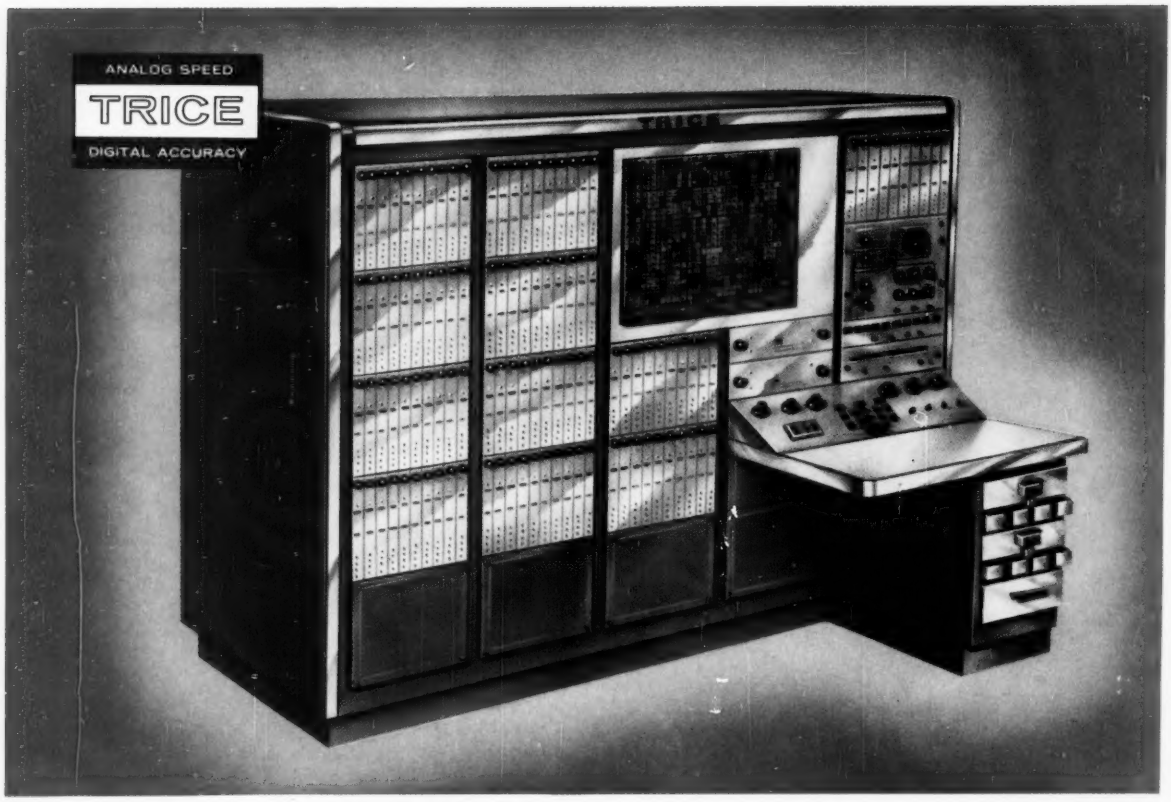

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SPEED: 100,000 iterations per second for each integrator achieved by 3 mc clock frequency and completely parallel operation.

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OUTPUT: Analog plotter or automatic typewriter

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For a polar resolver,

$$R = x \cos\theta + y \sin\theta$$
$$x \sin\theta - y \cos\theta = 0$$

With lag $\Delta\theta$, these equations become

$$R = x(\cos\theta_o - \Delta\theta \sin\theta_o) + y(\sin\theta_o + \Delta\theta \cos\theta_o)$$

$$x(\sin\theta_o + \Delta\theta \cos\theta_o) - y(\cos\theta_o - \Delta\theta \sin\theta_o) = 0$$

Rearranging:

$$R = (x \cos\theta_o + y \cos\theta_o)[1 + (\Delta\theta)^2]$$

$$\Delta\theta = \frac{y \cos\theta_o - x \sin\theta_o}{x \cos\theta_o + y \sin\theta_o}$$

For $(\Delta G)^2 << 1$

$$R = x \cos\theta_o + y \sin\theta_o$$

$$\Delta\theta = \frac{y \cos\theta_o - x \sin\theta_o}{R}$$

Using an electronic multiplier again, the "tweeter" channel is added as shown in Fig. 10.

Inasmuch as the "tweeter" channels for both the rectangular and polar resolvers should introduce corrections which are small compared to the signals through the "woofer" channels, the electronic multipliers can be relatively low in accuracy.

In many applications of resolvers where frequency response is a serious concern, the amplitude of an oscillation tends to decrease with increasing frequency. This helps to preserve the validity of the small-angle assumption, and in fact there would be many problems where the high-frequency oscillations would not even be excited so long as the resolver does not introduce spurious lags.

Example 6—General Multiplication

High-frequency paths can be provided for both the variables in a product using servos as follows:

$$x = x_o + \Delta x$$
$$y = y_o + \Delta y$$
$$xy = (x_o + \Delta x)(y_o + \Delta y)$$

For $x_o >> \Delta x$

$$xy \approx xy_o + x_o \Delta y$$

The circuit is then as shown in Fig. 11.

Matsuno on Improving Terminal Readout Accuracy

The next speaker listed on the program was *Bruno Ulrich* (Hughes Systems Development Laboratories, Culver City, Calif.), but the man who actually spoke was his colleague *Shozo Matsuno*, who was kind enough to furnish us with a brief, very brief, résumé of his talk as follows:

"My discussion consisted of a few specific techniques used in improving terminal readout accuracy of homing missile simulations. In particular, focus was directed to the improvement of terminal kinematics (geometry) representation of the missile system in order to achieve accuracy comparable to the accuracy of the over-all simulation.

"Two inherent problem areas which directly affect accuracy of terminal readout were:

"a. The presence of terminal singularity (overload problem).

"b. Large variation of variables (scaling problem).

"Compensations and techniques discussed were:

"1. Elimination of polar resolver in the geometry to improve terminal computer stability by utilizing the relationships:

$$\dot{R} = \dot{X} \cos\sigma + \dot{Y} \sin\sigma$$

$$\dot{R}\sigma = -\dot{X} \sin\sigma + \dot{Y} \cos\sigma$$

where

$$R = \sqrt{X^2 + Y^2}$$
$$\sigma = \tan^{-1}(Y/X)$$

"2. Continuous extrapolation technique to obtain miss-distance, avoiding the undesirable effects of the singularity.

"3. An extension of the extrapolation method to read out variables with high terminal rate of change (a variable y with high rate of change is redefined as $y = \bar{y} + \Delta y$. Now, a small term Δy is defined by minimizing its terminal rate of change. Then, Δy can be scaled up properly and will be less sensitive to readout timing).

"4. The use of time variable scale factor K(t) for reading quantities with large variation of its value, viz. missile-to-target range. Two methods of scaling were given:

"a. Continuously varying scale factor using the relationship:

$$(d/dt)(KX) = \dot{K}X + K\dot{X}$$

"b. Step change in scale factor:

$KX \rightarrow K'X$ where $K' >> K$."

Shozo tells us that he will be glad to furnish further information and details on the subject.

* * *

Third speaker on the program was *Lucien W. Neustadt* of Space Technology Laboratory, but as he did not send us any information on his talk, and nobody else reported on the subject, we don't know that he spoke (though he signed the register), and if he spoke, what he said. If Lucien will give us the word we will be happy to pass it on. Otherwise thus endeth our report on the July 1959 Western Simulation Council Meeting.

Information (Without Theory)

Thanks largely to *Dave Miller* (Colorado Research Corp., Broomfield, Colorado), there has been considerable Simulation Council-type activity in the Denver area. As a result, the SCI Board of Directors is serious-

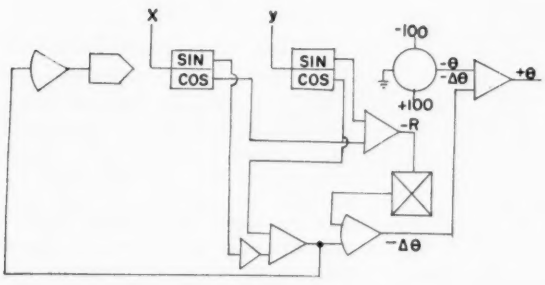


FIG. 10

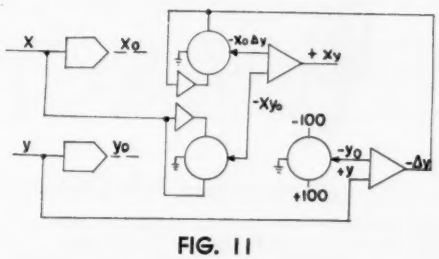
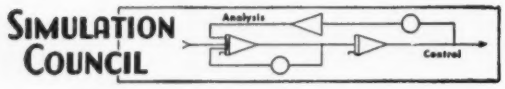


FIG. 11



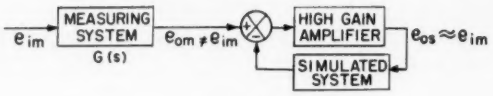


FIG. 12

ly considering a charter presented by this group as "The Rocky Mountain Simulation Council," pending adjustment of the territory that they will represent.

One of the objectives of the Simulation Council was, has been, and I hope is, to stimulate discussion. Somehow we have gotten into a rather formal rut where few people *talk back*. The correspondence touched off by my comments on McGregor's talk (*Newsletter* of July 1959) is very gratifying. The first response, that by *Martin Dost*, Junior Engineer in the Mechanical Analysis Laboratory, IBM, Poughkeepsie, N. Y., was as follows:

"Your coverage of W. K. McGregor's talk on the "Determination of Forcing Functions from the Response of a Known Physical System" in the July '59 *Newsletter* was of considerable interest to me, being to some extent familiar with analog computing and feedback control theory. Would you please let me know where I can obtain a copy of McGregor's paper.

"From abstract and block diagram of the postulated system it is not obvious to me how the error signal $-\epsilon_s$ is obtained. If the block in the feedback path (signified as "Feedback System") is another summing point that produces the difference of e_{is} and $e_{os} = e_{is} + \epsilon_s$, I can imagine to obtain $-\epsilon_s$. But is not $e_{is} + \epsilon_s$ the output of the open loop system with input e_{is} (similar to the measuring system, whose input is e_{im} and whose output is $e_{om} = e_{im} + \epsilon_m$). The closed loop system sketched, if well compensated, will yield an output $e_{os} = e_{is}$; where, therefore, does the error signal ϵ_s come from if the loop is closed?"

To this your Editor replied, with copy to Mac:

"Thank you for your letter of August 24. I have a very good reason for being so slow in answering. Every time I have intended to answer and reread McGregor's abstract, then my explanation, then your question, I got so confused that I put your letter aside and tackled something I could understand.

"If I read your letter correctly, we are in perfect agreement until the last phrase of the last sentence in which you ask where the error signal ϵ_s comes from if the loop is closed. The answer is that it comes from the block labeled Simulated System, just as it always did. Closing the feedback loop does nothing to the transfer characteristics of this block, but only alters the input so that instead of e_{is}, it now sees e_d the input. So for the *closed loop* the output e_{os} is now equal to $e_d + \epsilon_s$ instead of $e_{is} + \epsilon_s$. Because we have postulated a feedback system that will make this equal to e_{is}, which is equal to $e_{im} + \epsilon_m$, then we have: $e_d + \epsilon_s = e_{is} = e_{im} + \epsilon_m$, and as the error in both systems is the same: $\epsilon_s = \epsilon_m$ and $e_d = e_{im}$.

I hope that this explanation either clarifies the operation of the system or gets you as confused as I am."

The copy to McGregor elicited the full whammy—"The Extrusion of Transient Data from Instrument Systems by a Simulation Method"—to Dost as well as to your confused editor, who at this point was ready to give up. Mac's covering letter read as follows:

"Enclosed is a more complete treatment of the transient data correction method reported at the January meeting of the Southeastern Simulation Council. I really don't know if this is the same thing John McLeod said that I said or not. I think he has to swap *simulated system* and *feedback system* blocks to simplify the problem so that I can understand it. I enclosed also a "corrected?" diagram similar to Mr. McLeod's.

"I appreciate your interest and invite your comments always."

But back came bouncing Dost's reply:

"Thank you for your letter of September 22, concerning your note on Mr. McGregor's talk on the transient data correction method.

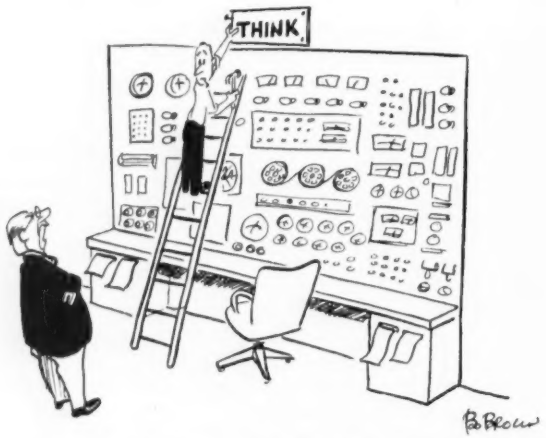
"After I received Mr. McGregor's original paper, I could understand the concept involved. I believe that the block diagram on p. 1050 should have looked like Fig. 12.

"The function of the control system, mechanized, e.g., by an analog computer, is to generate the approximate inverse transference of the measuring system and thereby to extend the frequency response of the measuring system greatly or yielding an overall transfer function of

$$KG/(1 + KG) \approx 1$$

because the gain K is assumed to be very large."

Now this sort of thing leaves ye Ed bewildered but fulfills the purpose of the Simulation Councils. Any chit-chat from youse guys?



"Really, Henshaw, I don't feel that's necessary!"

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Thot (not concerting)

Either I have no readers (hope Milt doesn't find out), or I am making no mistakes (impossible), or my mistakes are not very important, interesting, or amusing; or you guys have no spirit. How about another two-, three-, or multi-cornered discussion (or even a good rhubarb) like the McGregor-McLeod-Dost one?

SPEAKING WITH EASE®

An up-to-the-minute report on computer technology prepared by the **Beckman/Berkeley** *engineering staff*

New Advances in Recent Computer for Boeing

A 50 ft. EASE computer shipped to Boeing September 1, is worth looking at as a concrete example of what can be done with the new techniques and equipment we have been reporting in these columns. This all-electronic, digitally-controlled installation is a far cry from the first .01% computers that appeared three years ago. There's too little room to detail all the improvements that distinguish this polished product from the creatures of an earlier age, but let's run through a few more recent advances.

Coordinate Transformations at Electronic Speeds

The servo-resolver, one of the last vestiges of wheel-and-lever analog computing, has finally disappeared. Electronic sine-cosine generators now join with electronic multipliers to translate polar to rectangular coordinates and vice versa. This means that any problem involving resolution can now be handled at computing speed of integrators and summers, that is, at roughly 100 times the speed formerly possible. And accuracy, far from declining as was the case when the first non-linear electronic components appeared, is greater than that achieved with servo resolvers.

This computer can perform fourteen coordinate transformations simultaneously. Sines and cosines are generated with an accuracy of .05%, electronic products with an accuracy of .02%.

Amplifiers that drift only 20μv per week

Drift has been one of the most bothersome faults of amplifiers and one of the toughest engineering problems to lick. Amplifiers in this computer are conservatively specified to drift less than 20μv per day. Tests show a normal drift of less than 20μv per week. Drifting at this rate, the amplifiers require balancing only once a week to maintain .01% integrating accuracy.

The low rate of drift opens up another intriguing possibility: that of balancing grid current against the stable offset, cancelling both sources of error, and thus achieving unprecedented integrating accuracy. We have tried this technique with favorable results. For a detailed report write for "Speaking with EASE" article C14.

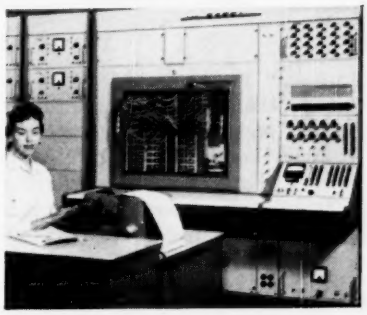
Better Centralized Control

Now you can do more and see more without leaving the console. To wit:

(1) The pushbutton selector enables the operator to inspect voltages at any of up to 1500 points in the computer. Voltages may be read to .01% on the digital voltmeter, to .001% using the analog-type null meter.

(2) Power supply currents can be measured at the console.

(3) A bank of close-set indicating lamps identify overloaded amplifiers by number.



One of two interlocked control consoles, showing Flexowriter used for programming, checkout and recovery of data either manually or by punched tape.

(4) The patchboard is laid out to order; thus assuring the best arrangement of terminals for the type of problem anticipated.

Complete Automatic Checkout

The DO/IT system will scan all desired points in the computer, compare voltages with the proper values, and print out the location of any discrepancies together with the actual value. This enables an operator to pinpoint errors due to patching, mechanization or faulty components without a moment's delay.

The computer has two control consoles. All operation may be directed from one console, thus creating a single large computer, or the installation may be split into two smaller computers, each employed on a separate problem.

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CIRCLE 69 ON READER-SERVICE CARD

Using Thermocouples With
Non-Standard Reference Temperature

How to read unknown temperatures (and predict emf output from given temperatures) accurately using reference junctions at any temperature.

ALVIN B. KAUFMAN
Litton Industries

THERMOCOUPLE-EMF relationships for selected reference temperatures are found readily in commercial and NBS publications. However, the practice of employing hot thermocouple references[1] makes the standard temperature-emf tables unusable, unless the techniques similar to that used for correction of the standard table to ambient reference is employed. A 0°F or 0°C ("0" mv) reference table cannot be used to convert temperature to equivalent millivolts simply by taking the temperature difference between the given and measured reference temperature and using this to determine the millivoltage output, because of the nonlinearity of the thermocouple-emf relationship.

First step in the correct procedure is to secure an emf-temperature table which represents accurately the emf-temperature relationship of the particular couple materials being used. These tables are based on fixed cold-reference temperatures, but this can be disregarded. Chromel-Alumel and most other couples have but one standard calibration in use. However, iron-constantan couples may be manufactured to two or more specifications,[2] such as the Industrial and Military, which are specified:

HOT REFERENCE junction maintains reference junction at an elevated temperature, such as 250°F.

Industrial—NBS RP2415, SAMA, ISA-J
Military—NBS 1080 or MIL-W-5845A, ISA-Y

After the proper thermocouple table is secured, two alternatives are possible:

1. Determination of temperature from an emf reading.
2. Determination of a millivolt reading expected from a selected temperature.

Determining Temperature from an EMF Reading

A. *Where unknown temperature is higher than reference temperature used*:

From the selected thermocouple table find the indicated millivolt reading expected for a temperature equal to the reference temperature being used. Add this to the actual measured emf. Using the corrected emf (sum), read out the measured temperature from the same table.

B. *Where unknown temperature is lower than reference temperature used*:

Again, find the mv reading for a temperature equal to the reference temperature being used. *Subtract* from this the actual measured emf. (Meter connection must be reversed to get the reading.) Read out the measured temperature from the difference emf thus established.

Determining EMF Expected from A Certain Temperature

A. *Where test temperature is higher than reference temperature used*:

From the selected thermocouple table find the millivolt reading for a temperature equal to the reference temperature being used, and also the expected millivolt reading for the given measurement temperature. Subtract the first emf (reference temperature used) from the second emf (test temperature) to get the expected emf using the hot reference.

B. *Where temperature is lower than reference temperature used*:

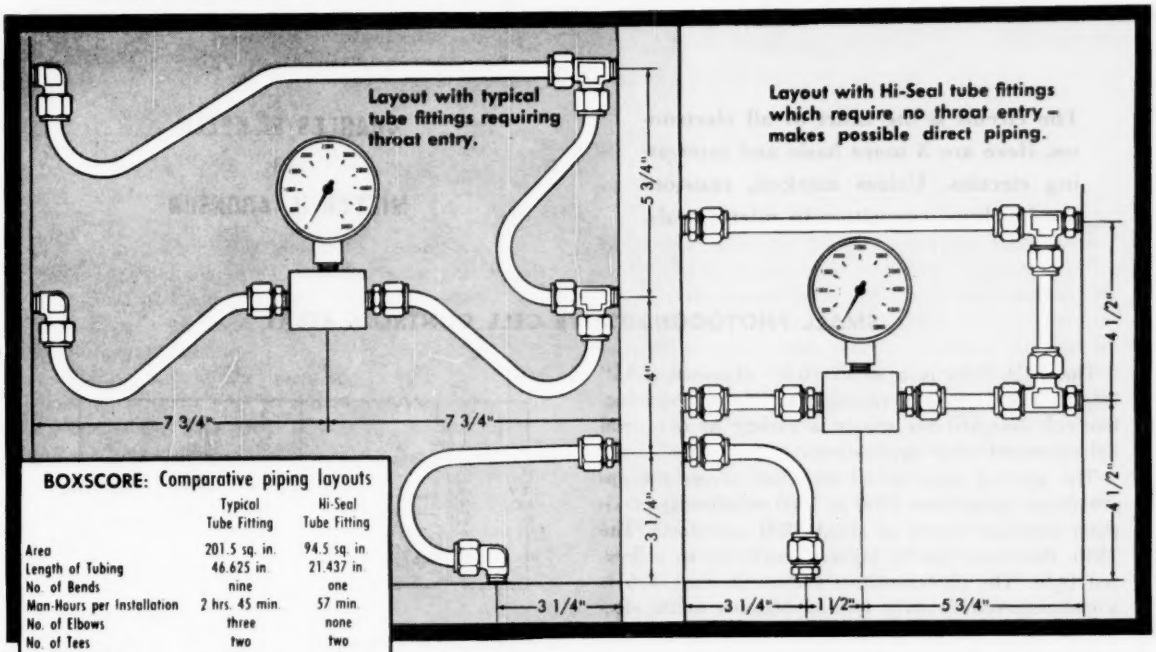
Subtract the test-temperature emf from the reference-temperature emf. (Meter connection must be reversed in order to get reading.)

References

1. Kaufman, A. B., "Hot Thermocouple Reference Junction vs. Ice Baths and Bridge Compensators, Engineering Bulletin: RJ application Series 1001, Arnoux Corp.
2. Dike, Paul H., *Thermoelectric Thermometry*, Leeds & Northrup Company.

IMPERIAL *Engineering and Data File*

ENGINEERED TUBE FITTINGS — VALVES — TUBING TOOLS



BOXSCORE: Comparative piping layouts

	Typical Tube Fitting	Hi-Seal Tube Fitting
Area	201.5 sq. in.	94.5 sq. in.
Length of Tubing	46.625 in.	21.437 in.
No. of Bends	nine	one
Man-Hours per Installation	2 hrs. 45 min.	57 min.
No. of Elbows	three	none
No. of Tees	two	two
No. of Straights	three	six

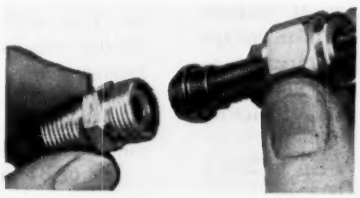
How Hi-Seal saves space—cuts costs

. . . makes possible reductions up to 50% in required piping area . . . up to 66⅔% in installation time!

Imperial Hi-Seal tube fittings open up economical *new piping design concepts* for instrumentation, hydraulic circuits, and other tubing installations. Hi-Seal makes possible far more compact layouts than can be made with conventional fittings — in addition, it brings *new ease and speed* to joint making and utmost reliability.

These design considerations are illustrated in the tubing layouts above. The diagrams show how Hi-Seal actually eliminated nine tube bends . . . saved more than one-half on tubing needed. Total layout area required by Hi-Seal is only 94.5 sq. in., compared to 201.5 sq. in., when an ordinary fitting is used. And 189% *more* manhours were required to tube up the circuit with a typical fitting.

Several key fitting design factors account for Hi-Seal piping economies: (1) Hi-Seal makes a positive butt joint — no need to spring tubing; (2) speedy, foolproof assembly — it is impossible for the fitting to be assembled with the alloy steel sleeve in reverse position; (3) there is no danger of over-torqueing . . . when threads on body of fitting are covered, a pressure-tight seal has been made, a visual assurance of a correct joint; (4) under tests, Hi-Seal fittings have withstood pressure of 4,000 psi at conditions of −320° F. to over 700° F.



with *no* leakage; (5) Hi-Seal fittings can be disconnected and reconnected as often as desired.

Complete line — Hi-Seal fittings are available in brass, steel, stainless steel. Also furnished in Titanium, Tantalum and other metals. Steel fitting supplied with cadmium plate or black phosphate finish. Conform to J.I.C., A.S.M.E. and A.S.A. standards. In sizes for ⅛″ to 1½″ O.D. tubing. Furnished with Long Dryseal pipe threads or straight thread port seal.

Write for Bulletin No. 3061

IMPERIAL

THE IMPERIAL BRASS MFG. CO.
6300 W. Howard St., Chicago 48, Ill.

In Canada: 18 Hook Ave., Toronto, Ont.

New high-pressure valves assemble directly to tubing — eliminate additional fittings

A revolutionary new line of Imperial needle valves designed for working pressures up to 5,000 psi., and temperatures to 450° F., employs Hi-Seal tubing connections.

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☐ No. 3061 ☐ No. 3096 ☐ Cat. No. 200

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City ..... Zone ..... State .....

CIRCLE 70 ON READER-SERVICE CARD

ELECTRONIC CIRCUITRY

The circuit is the heart of all electronics. Here are 3 more basic and interesting circuits. Unless marked, resistors are in ohms, capacitors in microfarads.

CHARLES F. KEZER
and
MILTON H. ARONSON

SMALL PHOTOCONDUCTIVE CELL CONTROLS RELAY

The RCA-7536 is a small (0.3″ diameter, 1.35″ length) side-on type of cadmium-sulfide photoconductive cell designed for use in a variety of industrial light-operated relay applications.

The spectral response of the 7536 covers the approximate range from 3300 to 7400 angstroms; maximum response occurs at about 5800 angstroms. The 7536, therefore, has its highest sensitivity to yellow-red light. The photosensitive surface in the 7536 is a cadmium-sulfide strip located between metal electrodes.

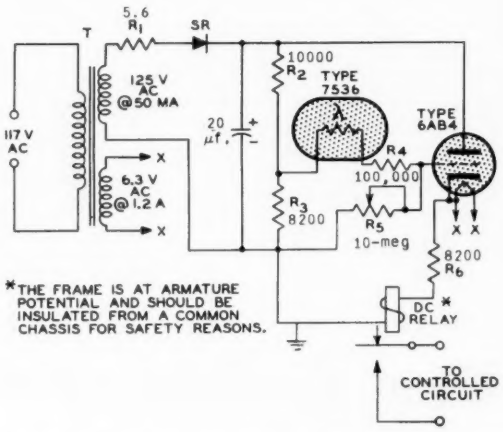
The 7536 is hermetically sealed to permit operation under conditions of high humidity. Median value of *radiant sensitivity* (the quotient of output current by incident radiant power of a given wavelength at constant electrode voltages) is 1580 ua/uw at 5800Å and voltage between terminals of 12 vdc. Median value of *luminous sensitivity* (the quotient of the output current by incident luminous flux, at constant electrode voltages) is 4.5 amp/lumen with voltage between terminals of 12 vdc; *Illumination sensitivity* (the quotient of output current by incident illumination, at constant electrode voltages) is 300 ua/fc (median) with voltage between terminals of 12 vdc; max current capability is 1000 ua; max power rating is 50 mw. The voltage between terminals of the 7536 may be applied without regard to polarity.

Photosensitive area is 0.2″ x 0.02″. Up to 200 v dc or peak ac can be applied across it.

A typical circuit for the 7536 is shown. In this circuit the relay is normally energized when light is incident on the cell. When the light is interrupted or the light level drops to a predetermined value, the relay operates. The potentiometer (R5) is employed as an adjustable load resistor for the 7536. It should be adjusted so that the photocurrent flowing through it will provide sufficient signal input for the 6AB4 to operate the specified relay (Sigma Series 11, Type 11F-6000 G, or equivalent).

Resistors R2 and R3 are 2 watts; R6 1 watt; others ½ watt. Transformer T is Stancor PA-8421, or equivalent; the silicon rectifier is RCA-1N1763.

Principle is as follows:



Cadmium sulfide has high resistance in the dark (several hundred megohms). This resistance drops substantially under light.

In the circuit, the silicon-diode half-wave rectifier develops a voltage of about 150 v dc across the capacitor. This is divided so that 68 v dc appears across divider resistance R3. The part of this voltage which appears across the photocell depends on its resistance.

In the dark the resistance of the cell is several hundred megohms; substantially all of the drop is across the cell, and grid voltage of the 6AB4 tube is near zero.

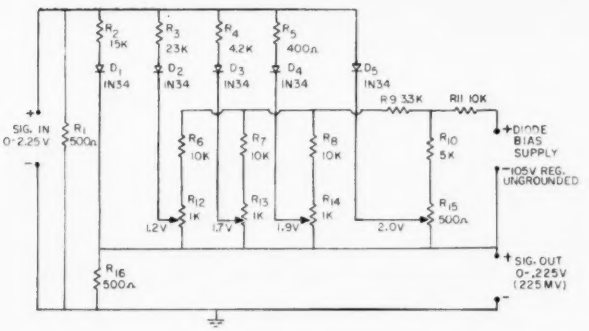
The 6AB4 tube is connected as a cathode follower; hence cathode current makes the cathode a few volts positive with respect to the grid. Relay resistance is 6000 ohms, in series with the 8200 ohms of R6. From the tube characteristic curves, it is seen that cathode current is too small to close the relay, which requires about 3 ma.

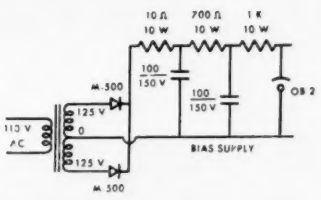
When light strikes the cell, grid potential of the 6AB4 rises, and current in the relay coil increases. At about 40 v grid potential, the 6AB4 will cause the relay to close, as cathode voltage is a volt or two higher, corresponding to 3-ma cathode current.

Advantage of using photoconduction cell rather than photoelectric cell is high illumination sensitivity and compact size.

Source: RCA Electron Tube Div., Harrison, N. J.

LINEARIZING CIRCUIT CHARACTERIZES SIGNAL





Bias supply for Linearizing Circuit.

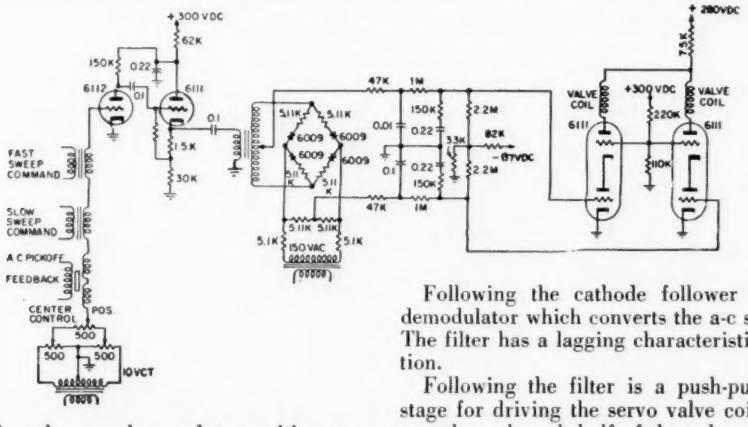
A gas analyzer used to measure n-heptane in exhaust emission had an output that was nonlinear with respect to hydrocarbon concentration. The output signal was made linear with respect to gas concentration by this linearizing circuit.

The operation of the linearizer is as follows: The signal current from the gas analyzer develops a voltage across R_1. This same voltage appears across the various series combinations of R_2 D_1 R_{16}, R_3 D_2 R_{16}, etc. Each of the diodes is biased to conduct at different input signal levels. This bias voltage is obtained from the regulated power supply shown. The ratio of each of the series resistors to R_{16}, the output resistor, determines the slope of the curve after each break point—i.e., after the diodes have begun to conduct.

The curve fitting was empirical. The calibration curve of the gas analyzer and the desired output curve were drawn on the same ordinates, and the required correction curve was readily obtained graphically. The number of diodes was determined by finding graphically the number of straight line segments that would fit this curve to within 2%. The slope of the lines connecting these inflection points determined the ratios of R_2 to R_{16}, R_3 to R_{16}, etc.

Source: Walter Grabowsic, J. Lunan and L. Balozer, Chrysler Corp., Detroit 31, Mich.; also ISA Preprint 13-59, "Electronic Instrumentation for Rapid Summation of Exhaust Emission."

SERVOMECHANISM AMPLIFIER FOR ELECTROHYDRAULIC ACTUATOR



An electrohydraulic valve can be used to position a plunger in a magnetron for frequency control. This servomechanism drives the servo valve at frequencies up to 20 cps, and positions the plunger to an accuracy of 0.001".

The input signal to the 6112 amplifier tube is a 400-cps signal whenever the 400-cps feedback signal (taken from a pickoff attached to the magnetron plunger) does not exactly cancel the 400-cps command signals (which sweep the frequency as desired). The feedback signal is taken from an LVDT (linear variable differential transformer). The LVDT used for feedback is actuated with 6.3 v, 400 cps; its sensitivity is 18.4 v/inch.

The a-c amplifier and cathode follower has a voltage gain of 32.

Following the cathode follower is a phase-sensitive demodulator which converts the a-c signal to a d-c signal. The filter has a lagging characteristic for servo stabilization.

Following the filter is a push-pull cascode amplifier stage for driving the servo valve coils. Nominal a-c current through each half of the valve coil is approximately 7 ma.

A phantastron circuit is used to generate a slow-sweep signal for the magnetron; a triangular wave generator generates the fast sweep.

Servo valve: Type 993D, a special type developed for GE, having the desired characteristics at an oil pressure of 600 psi.

B supply: 300 v regulated by VR tube. 280 v dc for driver, unregulated. —87 v dc derived from a 5783 gaseous regulator.

Source: C. H. Willard and C. A. Stemmer, Light Military Electronic Equipment Dept., General Electric Co.; also *Automatic Control*, November, 1957.

CLARE

NEW...

Clare printed circuit relays,
custom built to **your** design,
offer sensational savings
in space, weight, and cost
for modern data processing
and other high speed
switching devices

Relay mounted on **your** circuit board

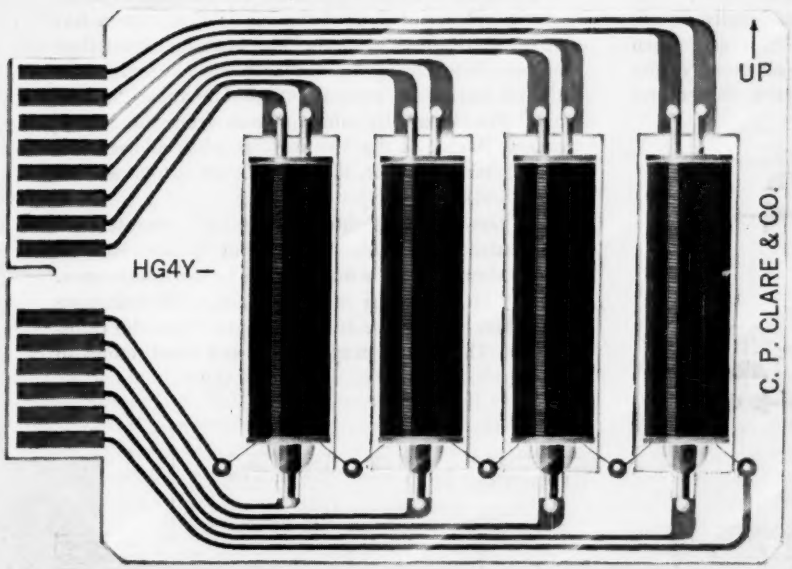
This outstanding relay assembly permits single or multiple installation of CLARE mercury-wetted contact relays in the small space of a printed circuit board. It plugs into a console in the same manner as the logic circuit it serves.

It brings to designers of data processing and data logging equipment all the proved advantages of CLARE mercury-wetted contact relays in the smallest possible space. Individual switch capsules and coils are affixed to the printed circuit board and sealed from dust, moisture and tampering by "Skin-Pack," a tough vinyl coating.

Let us show you how we would adapt your board to include either the standard HG relay or the ultra-high speed HGS . . . as well as other selected components.

CLARE mercury-wetted contact switch hermetically sealed in high-pressure hydrogen atmosphere. Life expectancy over a billion operations.

Each capsule is surrounded by individual coil which is custom-wound to suit the operating characteristics of the customer's application. *For full information on CLARE HG printed-circuit relays send for Bulletin CPC-4.*



Typical assembly

Send us your printed circuit board

Discover how you can save time, space and money . . . enhance the performance of your high-speed equipment . . . with CLARE printed circuit relays. Contact your nearby CLARE Representative, or address: C. P. Clare & Co., 3101 Pratt Blvd., Chicago 45, Illinois. In Canada: C. P. Clare Canada Ltd., P. O. Box 134, Downsview, Ontario.

CLARE RELAYS

FIRST in the industrial field

CIRCLE 71 ON READER-SERVICE CARD

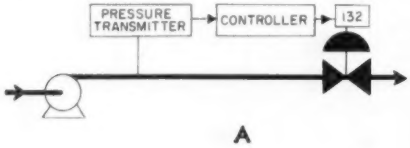
Process Control Systems

FRED D. MARTON, Instruments Publishing Company

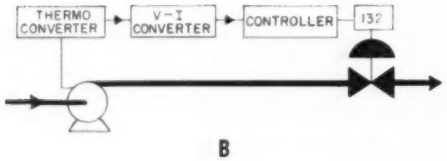
CONTROL OF PIPELINE PRESSURE VIA CONTROL OF PUMP SUCTION PRESSURE, DISCHARGE PRESSURE, AND PUMP MOTOR OVERLOAD

Pipeline pressure can be controlled by sensing the discharge pressure of a pump feeding into the line, and transmitting a proportional signal into a controller with a control valve in the line as the final element (A). It also can be controlled by measuring the current drawn by the pump motor, and using this variable to control the pressure via a thermo converter, a voltage-to-current converter, a controller, and a control valve (B).

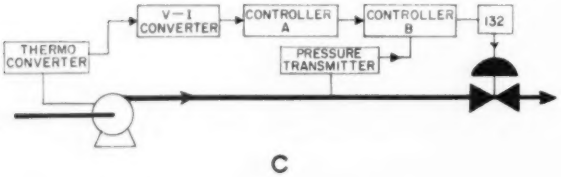
A *combination* of these two methods results in a sensitive cascade control system where one controller receives its signal from motor current consumption, and overrides a second controller operated from the discharge pressure (C). A working system is shown in (D). The control valve is normally wide open; throttling action is required only when the line pressure exceeds a safe upper limit, or when the suction pressure to the pumping station assumes a value below a safe minimum. However, when the set point of the pressure controller is reached, the output current rises beyond the 1-ma minimum and proportionally repositions the valve stem to close the valve. Similarly, when the suction pressure drops below the set point, action of the suction controller again throttles the control valve.



A



B



C

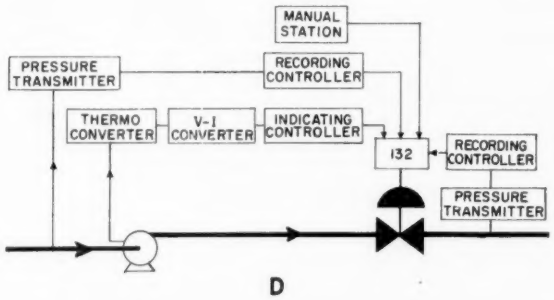
The thermo converter, in conjunction with the current converter, constitutes a safety device to protect the motor from overload. The thermo converter emits an electric signal in proportion to current drawn by the motor and detects an overload before a dangerous temperature rise. The current converter converts this signal to the 1- to 5-ma operating values of the controller.

Suction pressure is sensed also by a pressure transmitter (Type 145), and its output signal is fed into a recording controller (Type C110). The same is done with the pressure downstream of the control valve. The indirect means of measuring suction pressure (via the thermo converter) is used to feed a signal into a Type C120 indicating controller. The three output signals are electrically added into a final control signal wired to the valve positioner.

To facilitate startup, a Type 153 manual station is installed whose output signal can be used to buck the combined final control signal for the purpose of keeping the valve closed until the lubrication system has started to function properly. The bucking signal then can be eliminated by an on-off pressure switch in the lube oil line or by manual action. The valve then receives the electrically added signals from the 3 controllers. Output of the 3 controllers when added gives 3 to 15 ma. However, the valve is set to operate between 3 to 5 ma.

The pressure transmitters (Type 145) operate on a force-balance principle. The output is a linear d-c 1-5-ma signal which is not affected by a-c interference.

The C110 recording controllers and C120 indicating controllers receive the 1-to-5-ma signal from the transmitters. They have proportional and reset mode of



D

control and combine their 1-ma-minimum signals so that the valve positioner will be set to operate the valve in a range of 3 to 5 ma. The valve positioner also works on a force-balance principle.

The thermo-converter output signal is a voltage which is converted by the voltage transmitter (Type E700) into a standard 1-to-5-ma signal for use in the controller.

The 132 is an electro-pneumatic converter and positioner for operating diaphragm valves.

Source: Manning, Maxwell & Moore, Inc.; also Application Bulletin 8.0.

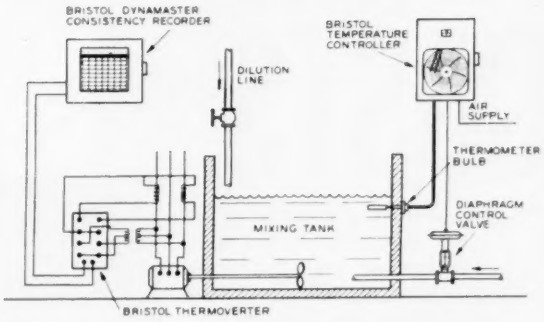
CONSISTENCY RECORDER USES AC/DC TRANSDUCER AS SENSING ELEMENT

Various methods can be applied to measure consistency of a solution. One method used extensively in the paper industry utilizes the measurement of the total power required by an electric motor to drive a mixer or agitator in a tank containing the pulp slurry in question.

In this system the total load on the a-c motor is sensed by a thermoverter (one or two-element depending on a-c motor). Its output, a d-c millivoltage, is then fed to a Dynamaster potentiometer indicator recorder. Since the total power consumed by the motor is proportional to consistency, the indication and record is that of the slurry consistency.

Control of the consistency can be effected automatically by the addition of a pneumatic control unit to the Dynamaster which has proportional and reset action. The pneumatic controller output will operate a control valve in the dilution line.

Temperature, where it affects consistency or viscosity, can be controlled by a circular chart single-pen recording controller. The thermal system of this instrument would



be of the class II vapor pressure type. The controller with proportional action (reset if necessary), would regulate the steam or other heating medium supply to the slurry.

Source: The Bristol Company, Waterbury, Conn.; also Bulletin P-1245-A "Dynamaster Electronic Instruments."

OVERLOAD CONTROL SYSTEM FOR DUAL COMPRESSOR MOTOR

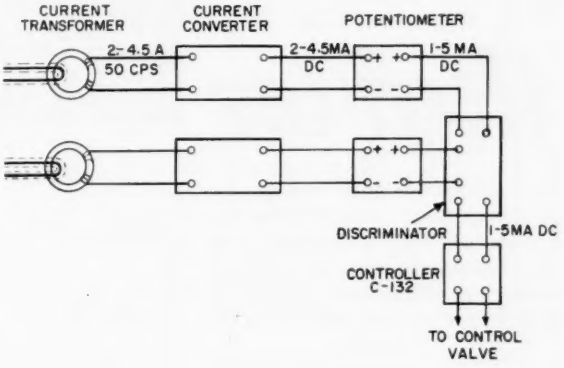
This system prevents motor overload where two compressors work in parallel.

Compressor loads are measured by determining the single-phase power to each motor. To get the proper control signal, the single-phase high-voltage current is transformed in a Weston Model 604 current transformer to a signal of 2-to-4.5 amp, and converted in a Weston Model 9866 current converter into a d-c signal of 2 to 4.5 ma, and further reduced to the required 1-to-5-ma dc input signal by a Type E-721 Potentiometer. Two signals on this order, originating from the two compressor motor windings, are then fed into the *discriminator*.

The Model C-132 electronic controller has proportional and reset mode of control.

High-load conditions can arise from two operating conditions: (1) from exceeding the set load value on either of the two compressors running at equal loads, or (2) from an unbalance between the two compressors, either when one stops or when one compressor starts to assume a greater share of the load.

In case (1), the signal discriminator would pass an average signal as long as the two loads are equal. When the set point is exceeded, the controller starts control action. Set point can be set at any value between 80 and 180 amps. When the average value is below set point, output from the controller will be 1 ma or less, corresponding to normal load conditions.



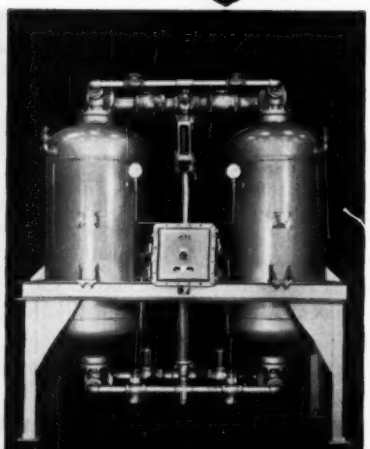
In case (2), the amount of unbalance that triggers action will be ±4%, as determined by the discriminator. The higher of the two signals will be switched into the controller. When the value exceeds the set point on the controller, the output signal to the control valve increases above the lower limit of 1 ma up to 5 ma and more, as long as the load exceeds the set point. To correct this condition the operator will have to either balance the loads on the two compressors (via manually operated throttle valves) or reduce the process load signal, external to the system.

Source: Manning, Maxwell & Moore, Inc.

REDUCE MAINTENANCE COSTS

Moisture and oil in your air system will result in costly repairs, down time, and even system failure. Moisture causes rust that clogs delicate sensing devices, slows down pneumatic controls, and in some cases, brings about total destruction of expensive equipment. Random oil in an air system forms sludges, gums and hard varnishes, causing instrumentation and control breakdown.

TRINITY



DESICCANT DRYER

Heat-Les

The Trinity Heat-Les dryer makes possible the driest air of all, and at the same time eliminates oil. This amazing dryer is being used in hundreds of industrial and military installations, and establishing new records for dependability, economy and performance.

Dewpoints to -200°F.
Low initial cost.
No heaters to replace or power.
No increase in air temperature.

Heat-Les dryers are available in many sizes, for all pressures, from 1 scfm to 5000 scfm. Larger volumes may be handled through combinations of units. Also, in complete, unitized dry air systems, including compressor, accumulator and instrumentation.

• *WRITE FOR COMPLETE DETAILS . . .*

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World leader in dry gas systems

Heat-Les Dryers • Heat-reactivated Dryers
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TRINITY EQUIPMENT CORPORATION, CORTLAND, NEW YORK
CIRCLE 72 ON READER-SERVICE CARD

BOOK REVIEWS

Continued from page 32

Radio Stations, Installation, Design and Practice, by G. A. Chappel, [c1959] Pergamon Press, 122 E. 55th St., New York 22, N. Y. 248 p., 8½", clothbound $7.50. Written for the student as well as the design engineer, and includes design of small stations which are in the majority throughout the world.

CIRCLE 167 ON READER-SERVICE CARD

Fourier's Series and Spherical Harmonics, by William Elwood Byerly, [c1893] Dover Publications, Inc., 180 Varick St., New York 14, N. Y. 287 p., 8", paperbound $1.75. Published in 1959 as an unabridged and unaltered republication of the last edition. An elementary treatise of the subject, valuable as handbook or reference. Includes 190 problems, approximately half with answers, and large bibliography.

CIRCLE 168 ON READER-SERVICE CARD

Boundary Problems in Differential Equations, edited by Rudolph E. Langer [c1960] The University of Wisconsin Press, 811 State St., Madison, Wis., 324 p., 9¼", clothbound $4.00. A collection of nineteen papers delivered at a symposium conducted by the Mathematics Research Center, U. S. Army at the University, April 20-22, 1959, which included American, Dutch, English, German, Italian, and Scottish scientists.

CIRCLE 169 ON READER-SERVICE CARD

Automation Today and Tomorrow, by L. Landon Goodman [c1958] Essential Books, 1600 Potlitt Drive, Fair Lawn, N. J., 158 p., 8½", clothbound $7.20. A technical survey of current progress, primarily from the European standpoint. More than half of the book contains a bibliography of "the automatic factory."

CIRCLE 170 ON READER-SERVICE CARD

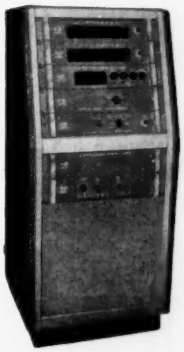
Basic Electricity and an Introduction to Electronics, by the Engineering Staff of Howard W. Sams & Co., Inc. [c1959] Howard W. Sams & Co., Inc., Indianapolis 6, Indiana, 172 p., 11", paperbound $3.60. Written for the student and beginner, explains the basic laws of electricity and magnetism, including ac and its measurement and control, to the threshold of electronics where the vacuum tube and the transistor make their appearance.

CIRCLE 157 ON READER-SERVICE CARD

With

THE DIFFERENCE IS IN THE QUALITY

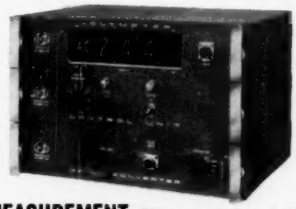
Quality Digital Systems
For Finite Measurements
In Infinite Applications



Unique unit construction affords simple development of "systems that design themselves" . . . systems that are "custom-made" with standard digital units.

Monitoring, control, check-out, inspection, calibration, research and development . . . just a few of the applications possible on small or large scale with Cubic Digital Systems. Almost every phenomenon of science or nature is a potential application for instrumentation to make your job easier, faster, more successful. The difference with Cubic instruments is the superior quality of their design and construction.

DC MEASUREMENT: Four and five-digit Cubic DC Voltmeters combined with the Control Unit provide instrumentation for bench-top use or for simple insertion into elaborate systems.



AC MEASUREMENT: The superior AC Converter Unit expands a systems capability for rapid, accurate measurement of AC voltages. Automatic or manual ranging models are available.

RESISTANCE MEASUREMENT: Built with Cubic's years-ahead design and careful attention to fine detail, the Ohmmeter gives rapid, accurate measurement of resistors and resistance materials.

VOLTMETER UNIT, featuring front and rear panel input terminals and wide output capabilities for multiple applications. Models V-41, V-51.

AC CONVERTER UNIT, featuring high input impedance, extreme stability, linearity and accuracy. Models AC-1 (Manual Ranging), AC-2 (Automatic).

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CIRCLE 73 ON READER-SERVICE CARD

Journal of the S C M A . . .

SOUTHERN CALIFORNIA METER ASSOCIATION

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ORIFICE METERING

THOMAS J. FILBAN
Daniel Orifice Fitting Co.

Development of the flow coefficient, correction factors, and present metering problems.

A FRENCH document, *Mesure des Debits des Fluides* includes a statement that orifice measurement was recommended by one Sextus Frontinus in his book, *De Aqueductus Urbis Romae,* during the reign of the Emperor Nerva in the year 90 B. C. We are told that the Chaldeans used a type of orifice metering and that baths and pools in the ruins of Pompeii were found to be equipped with orifices.

In the early days of gas lighting in our country a certain fixed fee was charged for all the gas the customer could use during some fixed period of time. As the demand for gas and the number of customers increased, this flat-charge method became unworkable.

The early wet-type meters and, later, the diaphragm meter, served a useful purpose for a number of years, but again were outmoded when it was realized that they were not adequate for the capacities demanded at points of large flow.

The proportional meter then came into being and had a brief experimental life. In this meter the gas was divided into two streams. The smaller of the two flows is metered by the conventional diaphragm or wet meter and is multiplied by some factor to give the total flow in both streams. The large rotary-type meter then was developed and became one of the most useful volumetric types of meter.

It finally was realized that an inferential-type meter was most practical. The thermal meter is one example of this type of meter; the amount of heat necessary to raise the temperature some predetermined amount is measured, and the volume calculated from the temperature rise, the amount of heat added, and the specific heat of the gas.

Another inferential meter is the *velocity-type meter,* among which are the devices which employ a constriction to increase the velocity component with a corresponding drop in the pressure component. The differential pressure (drop in pressure) over the constriction is an indication of the volumetric rate of flow. This type of device includes the Venturi tube, nozzle, and the orifice.

Of these devices, the thin-plate, sharp-edged orifice quickly became most popular. It is simple, comprising only a plate with a hole in it, inserted in the pipe. Internal diameter and surface roughness of "meter tubes" can be controlled closely, and the orifice can be bored to an exact diameter. With modern instrumentation we can measure the factors that affect flow—temperature, pressure, density, and viscosity of the flowing medium. Aside from these factors the empirically-determined *flow coefficient* is the only unknown remaining to be evaluated.

Flow Coefficient Defined

The actual rate of flow through a meter of the head type is almost always less than the flow calculated by the theoretical flow equation due to the ratio of effective areas of the vena contracta and the orifice itself. The vena contracta, just downstream of the orifice, is the place where there is the smallest area of flowing fluid. The ratio of actual to theoretical rates of flow is defined as the *coefficient of discharge*:

$$C = \frac{\text{Actual rate of flow}}{\text{Theoretical rate of flow}} \qquad (1)$$

If the rates are volumetric rates both volumes

February Meeting: Thursday, the 21st, Rio Hondo Country Club, Downey, Calif.
Feature: To be announced.

must be referred to the same conditions. C is simply an empirically determined correction factor to account for the vena-contracta effect.

The vena contracta, and hence the coefficient of discharge, also is affected by the ratio of orifice diameter to pipe diameter (β). The effect of β on the fluid is to alter the velocity of approach and the vena contracta, according to the relationship $\sqrt{1-\beta^4}$, which is called the *velocity-of-approach factor*. The well-known flow coefficient is simply:

$$K = C/\text{velocity-of-approach factor} = C/\sqrt{1-\beta^4} \quad (2)$$

The fact that C or K is a pure number makes its use universal because any compatible system of units will yield the same numerical value.

Determination of the Flow Coefficient

To determine the coefficient it is necessary to begin with Bernoulli's equation:

$$V_2^2 - V_1^2 = 2gh \quad (3)$$

where h is the difference in heights above some reference plane necessary to account for the difference in velocities.

If we define any two sections of the pipe along which the fluid is flowing as A_1 and A_2, and let q be the theoretical volume of flow, it follows that:

$$A_1V_1 = A_2V_2 \quad (4)$$

$$V_1 = q/A_1 \quad (5)$$

$$V_2 = q/A_2 \quad (6)$$

Substituting (5) and (6) into (3) gives:

$$q = A_2\sqrt{2gh}/\sqrt{1-(A_2/A_1)^2} \quad (7)$$

If both areas A_1 and A_2 are the same height above the reference plane—that is, if the pipe is horizontal, then h can be expressed in terms of the flowing fluid as:

$$h = (p_1 - p_2)/\rho g \quad (8)$$

where ρ is specific gravity of flowing fluid. Substituting (8) in (9):

$$q = \frac{A_2\sqrt{2(p_1-p_2)/\rho}}{\sqrt{1-(A_2/A_1)^2}} \quad (9)$$

This is the theoretical hydraulic equation. If we consider the sections of A_1 and A_2 to be circular, with diameters d_1 and d_2:

$$A_2/A_1 = (d_2/d_1)^2 = \beta^2 \quad (10)$$

$$q = \frac{CA_2\sqrt{2(p_1-p_2)/\rho}}{\sqrt{1-(\beta^2)^2}} \quad (11)$$

where C is added to account for the coefficient of discharge.

$$q = KA\sqrt{2(p_1-p_2)/\rho} \quad (12)$$

In terms of *weight* rate of flow (multiplying each side by ρ), this equation becomes:

$$W = KA\sqrt{2\rho(p_1-p_2)} \quad (13)$$

This hydraulic equation can be used to determine K. If we have a fluid whose properties are well known (such as water), we simply determine the exact area of the orifice (A), record the differential pressure ($p_1 - p_2$), determine fluid density (ρ) by means of the flowing temperature and pressure, and weigh the fluid metered during a timed interval. These quantities, easily determined in the laboratory with accuracy, can be substituted into the theoretical equation, which is then solved for the remaining unknown (K).

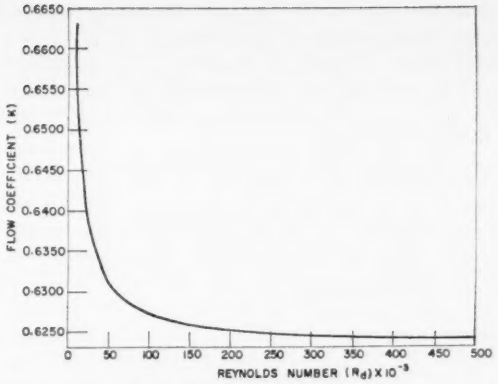

FIG. 1. FLOW COEFFICIENT versus Reynolds Number.

Influence of Reynolds Number

If V is the mean speed of flowing fluid at any plane within the orifice throat or pipe, ρ the density of the fluid, μ the viscosity, and d the diameter of orifice, the entire nature of the flow through the orifice is completely determined by the value of V, ρ, d, and μ. These are the basic variables.

A dimensionless combination of these variables is called *Reynolds Number* and is used as a correction factor to account for changes in viscosity, primarily.

The numerical value will always be the same for any system of units as long as the same system is used in evaluating all factors. It is by the use of Reynolds Number that a meter can be calibrated with water for service on gases because this criterion relates the various aspects of velocity metering.

The pipe Reynolds Number is

$$R_D = \rho VD/\mu$$

The orifice (throat) Reynolds Number is

$$R_d = \rho Vd/\mu$$

where D is pipe diameter, d is orifice diameter, ρ is density, V is velocity, μ is viscosity.

Note: as $\beta = d/D$, $R_D = \beta R_d$

Fig. 1 shows that there is a value of R_d for every value of K. There is an infinite number of such curves, one for every Beta ratio. Note that K can be plotted against R_D or R_d, and that C also could be plotted versus R_D or R_d. The four curves are interchangeable by the relationships

$$K = C/\sqrt{1-\beta^4},\ R_D = \beta R_d$$

Professor S. R. Beitler of Ohio State University discovered during early experimental work on

orifices that a plot of K against the square root of the reciprocal value of the Reynolds Number is a straight line. A family of straight lines is generated for a series of orifices of different Beta ratios. However, this is not true for exceptionally low values of Reynolds Number.

Also, because $K = C/\sqrt{1 - \beta^4}$ and $R_D = \beta R_d$, either C or K can be plotted against $\sqrt{1/R_d}$ and the four possible plots for any particular orifice can be converted one to the other simply by changing the coordinate scale.

A further advantage of this method of plotting is that as Reynolds Number approaches infinity, the value of K_o approaches the Y intercept from the point-slope equation for a straight line. The value of K then can be represented by:

$$K = K_o (1 + A\lambda) \qquad (15)$$

If a great number of plots are examined and correlated, it is found that any well-constructed orifice will yield values of K which can be represented adequately by equation (15). This also indicates that the slope is always present even at the higher values of Reynolds Number.

Some general observations made from recent analyses on experimental work are that K_o increases with β up to the point where $\beta = 0.7$; this increase is roughly related to β^4. Generally speaking, the slope coefficient also increases with β, although it is noticeably affected by the edge thickness of the orifice. It has been noted in our laboratory that there appears to be some slight change in K with changing edge thickness up to about 0.02 D.

To size an orifice, one assumes a trial Reynolds Number and K to determine a trial orifice size. Using this orifice size a second Reynolds Number is calculated and a corresponding K determined. Theoretically this would go on (by trial and error) until the correct K was pinpointed. With present tables and formulae it is seldom necessary to go beyond the second step. Orifices are sized (where possible) to put the Reynolds Number out on the flat portion of the curve.

The Effects of Expansion

If the Reynolds Number is large, say $R_d = 200{,}000$, the value of C, or K, determined by water calibration is sensibly independent of flow, showing that the effects of viscosity are inconsequential. However, if the same orifice is tested with air, the value of the flow coefficient varies with the rate of flow even though R_d is at a still higher value. This variance is due to the change in density which accompanies the change in pressure from p_1 to p_2 as opposed to the constant density of a liquid under a pressure drop of the same magnitude.

In 1929 a large number of tests were conducted in Los Angeles concerning the effect of expansion of natural gas. These tests were under the direction of H. S. Bean of the National Bureau of Standards. As a result of this and subsequent work, the expansion factor was found to be linear function of the pressure ratio P_2/P_1. When extremely high or low Beta ratios were included in the plot, some deviation from a straight line was apparent, but between the generally-accepted limits of $0.15 < \beta < 0.75$, a straight line was most representative of these points. The equation of this line is given in the literature as:

$$Y_1 = 1 - (0.41 + 0.35\beta^4)(x/k) \qquad (16)$$

where the subscript 1 indicates that the expansion factor is based on the upstream absolute pressure, and x is the ratio of differential pressure to static pressure.

The Effect of Compressibility

If all measurement could be carried out at relatively low pressures, say less than 50 psig, the deviations from the ideal gas laws would probably not be of sufficient consequence to cause concern. As we measure at higher pressures, it becomes necessary to apply a corrective for the *compressibility effect.*

A number of individuals have devoted considerable time to develop complete tables of correction factors for gases, either pure or mixed, at various pressure-temperature combinations.

When dealing with gases at ranges beyond the limits of the old tables we have no recourse but to calculate this property by some equation of state. A convenient equation is:

$$PV = ZNRT \qquad (17)$$

It is convenient to use the English system of units (N is pound moles; R has a value of 10.71 when P, V, T, are written respectively as psia, cubic feet, and degrees Rankin).

The value of Z depends on experimental determinations.

Base Temperature, Pressure

One of the greatest disadvantages of metering in terms of volumetric rather than mass rate of flow is the necessity of defining base conditions. The three most common temperature bases are 32°F, 60°F, and 68°F. A large number of pressure bases are used throughout the country, with about five of the most common lying between 14.4 and 15.025 psia. The change in bases is a relatively simple operation as only a linear relationship is involved.

In general, handbook equations are set up on the basis of assumed values of pressure, temperature and specific gravity.

Metering Problems

Range of flow

Today we accept ranges of flow of 70 or 80 to 1 in the natural gas field with at least one instance of a 200 to 1 range. In the realm of test cells we have successfully used an orifice meter to cover a range of 1000 to 1.

Two-phase Flow

Suppose that the liquid happens to be something like Butane which boils at 33°F. Unless the pressure is kept sufficiently high, it is possible that some vaporization will occur in the pipeline itself. This condition may be further augmented by the small pressure drop as the Butane passes through

the orifice. Experience has shown that in one case this condition caused a 30% error in measurement. Increasing the pressure to an appreciable degree brought the measurement back within its original 1% tolerance.

We do not yet have adequate data for metering two-phase flow. *Liquid oxygen* and *liquid nitrogen* at some missile installations are being successfully metered by orifices. Here, a temperature-pressure problem had first to be overcome to insure against two-phase flow.

Orifice metering of molten sodium is apparently being accomplished in some laboratories. No accuracy figures have been released as yet.

Plate Encrustation

Dry, clean, natural gas presents no difficulties in measurement. If, due to temperature changes, liquid drops out of the gas just upstream of the orifice, or if the gas is dirty so that an encrustation takes place on the upstream face of the orifice, drastic changes in metering accuracy can result. Recently a 30″ meter tube metering coke-oven gas at an eastern steel plant was dismantled due to peculiar results on the charts. It was found that reasonable facsimiles of Venturi-tube entrance and exit cones were being formed on the upstream and downstream faces of the orifice plate due to the tar deposited by the gas stream.

Segmental Orifices

The use of *segmentally bored orifices* is becoming widespread for the measurement of liquids or gases with suspended solids. The accuracy is generally considered to be in the region of 2½%. Pulp solutions in paper mills, untreated brines and slurries in the chemical industries, food processing, are applications.

Most recent of the newer innovations is the quarter-circle or *quadrant orifice* developed for fluids of high viscosity. The orifice incorporates a rounded edge of definite radius which is a particular function of the orifice diameter. The coefficient is between that of the orifice and nozzle or Venturi tube and remains constant up to a Reynolds Number of approximately 400,000, which is ample for many applications.

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The S.C.M.A. Handbook

ONE of the main purposes of the Southern California Meter Association, as originally conceived, was to compile a booklet of systematically arranged information pertaining broadly to fluid meters, instruments or controllers, and publish the same over the name of the Association.

This the Association has done for the last 25 years. The book has been widely used by Engineers and field men in the gas and oil industries. The range of material covered is indicated by the sample index and data sheets shown here.

The handbook sells for $7.50 to members of the Association and $10.00 to non-members. Inquiries should be directed to the Secretary of the S.C.M.A.

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SECTION ONE

MEASUREMENT OF GAS FLOW GENERAL

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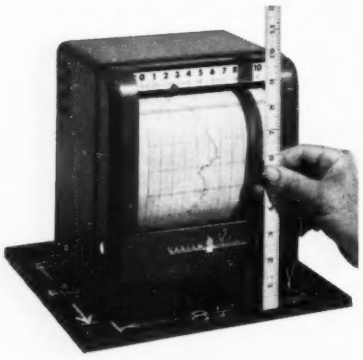

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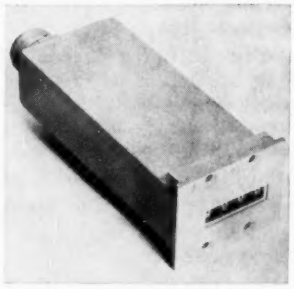

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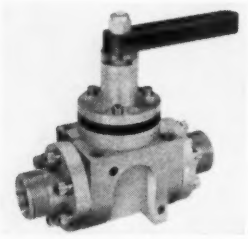

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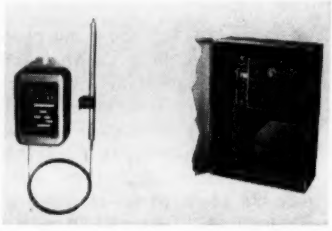

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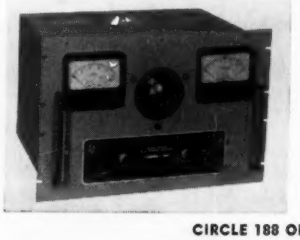
AIRCRAFT BATTERY SUBSTITUTE



New Model KM88 Aircraft Battery Substitute has now extended d-c output voltage range to 0-30 vdc at the full load rating of 20 amp. Maximum rms ripple has been reduced to be within ½% of the average d-c output. —*Opad Electric Co., 43 Walker St., New York 13, N. Y.*

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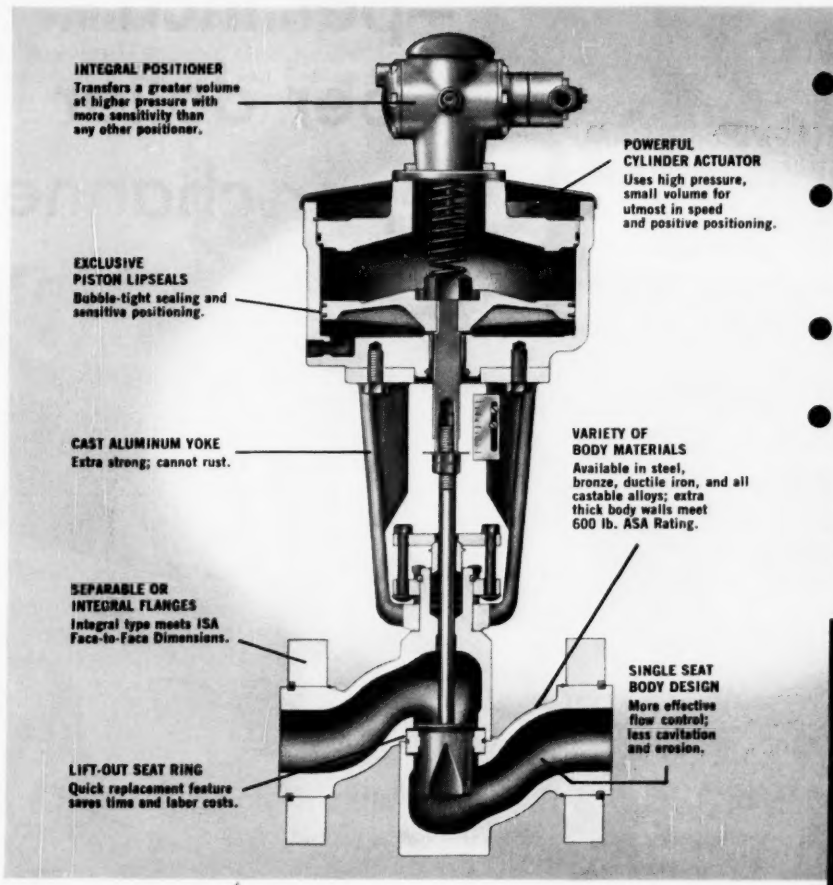
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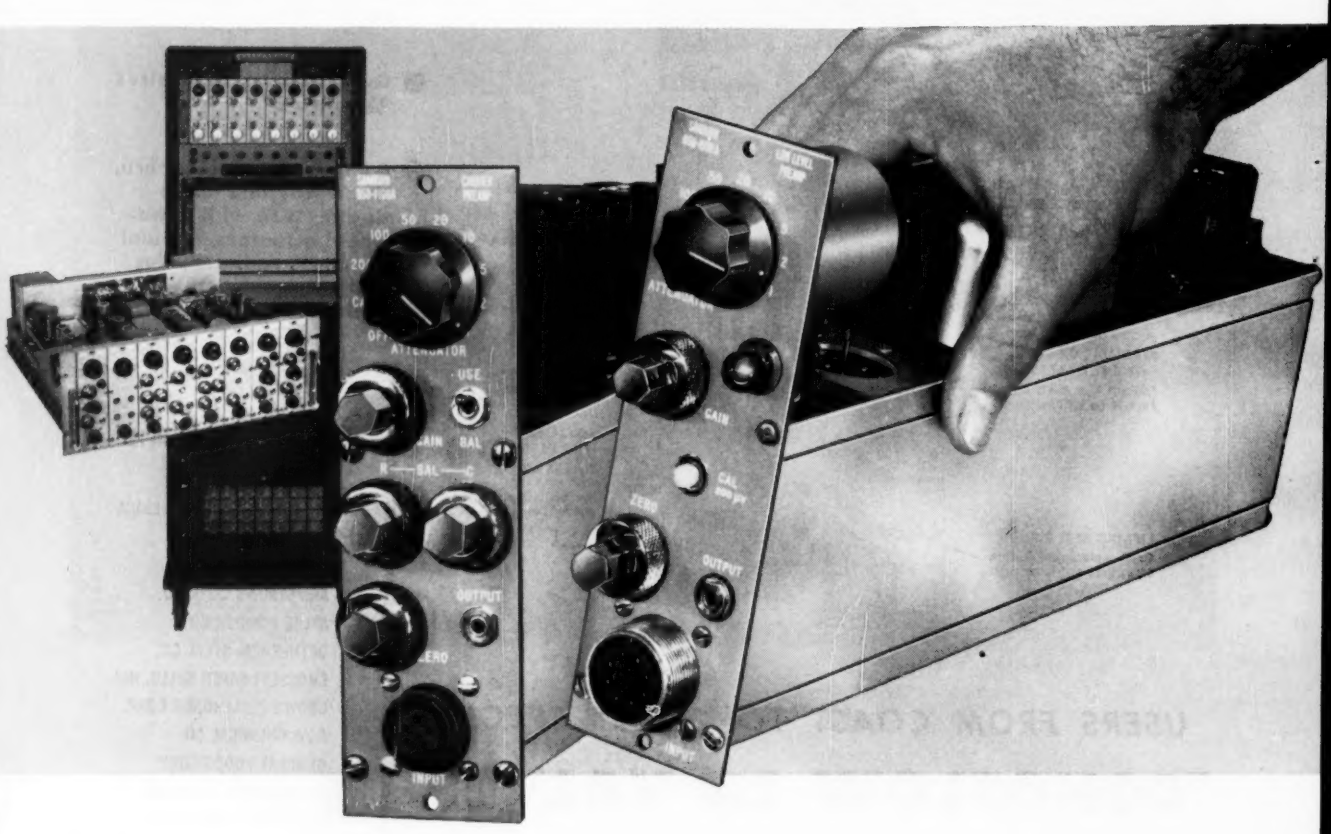

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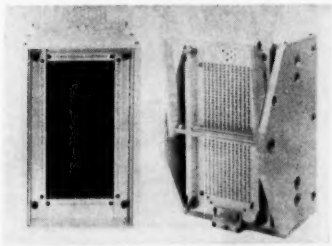
PUNCHED CARD SENSOR

New Static Punched Card Sensor, adaptable to both IBM and Remington Rand card users, features stand-

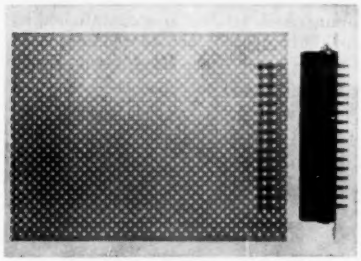


ard taper tab receptacles which connect users' leads to sensor switches, switch isolation, and ruggedized construction.—*Taurus Corp.*, 8 *Coryell St., Lambertville, N. J.*

CIRCLE 189 ON READER-SERVICE CARD

PLUGBOARDS

New Plugboards facilitate printed-circuit designs and testing in prototype. Supplied in $\frac{1}{16}$" thick epoxy paper material with 0.062" holes on alternate intersections of 0.1" grid,

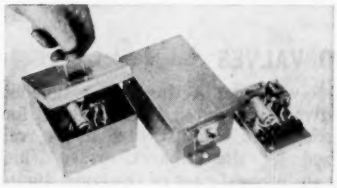


they have a 16-pin Elco Varicon Series-5001 connector attached to the leading edge which mates with a Varicon Series-7001 16-contact receptable.—*Vector Electronic Co.*, 1100 *Flower St., Glendale* 1, *Calif.*

CIRCLE 190 ON READER-SERVICE CARD

PULSE CONTROLLER

New Pulse Controller Series PC-600, designed to extend or shorten the duration of an electrical impulse, is made in three models: The PC-600,



PC-601, and PC-602. Each varies according to the type of mounting and enclosure desired, and adjustability varies from 30 to 500 msec. Only 15 msec are required to recharge the system, and there are only 5 msec lag from start of input to start of output pulse.—*Warco Industries, Inc.*, 6625 *Delmar Blvd., St. Louis, Mo.*

CIRCLE 191 ON READER-SERVICE CARD

ORIGINAL

instrumentation for most

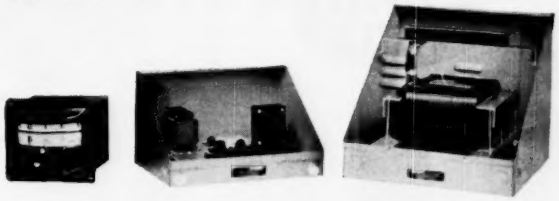
precise temperature control

NOW UNIVERSAL:

controls the most unstable temperature systems

Gardsman by WEST

Model JSB Stepless Controllers



For any operation requiring precise control of any temperature, through electric heaters, money can't buy a finer instrument. *Infinitely* modulates heater power. No on-off pulses; prolongs heater-life and saves power. Now provided with exclusive manual switch and adjustable maximum and minimum input control. *Tubeless.* Compact. Requires least maintenance and operating attention.

The most compact programming system available includes Model JSBG (left) for any operation involving a time-temperature cycle. Its simply cut cams integrate and control time with temperature.

Check the features that permit longer runs, assure uniform top quality, cut operating costs. Ask your West representative or write direct for Bulletin JSB and JG.

WEST Instrument CORPORATION

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British Subsidiary:
WEST INSTRUMENT LTD.,
52 Regent St., Brighton 1, Sussex
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See us at the ISA Instrument-Automation Conference & Exhibit, Houston, Texas, Sam Houston Coliseum, Feb. 2-4, 1960. Booth 338-336.

the trend is to WEST

CIRCLE 78 ON READER-SERVICE CARD

an economical new line of

DIGITAL TEST EQUIPMENT

New low-speed, low-cost version of Digital's unique patchcord-interconnecting building block test units.

NEW 3000 SERIES

Coordinated logic packages
Operate at any speed up to 500 kc.
Directly compatible with 5 mc. line
Priced as low as $43.00 per unit

Graphic front panels — a Digital first — make the 3000 Series ideal for educational uses. Also a great time- and work-saver in test and development projects. Write for complete information on this new line of high quality, high reliability DEC Digital Test Equipment.

digital

EQUIPMENT CORPORATION

MAYNARD, MASSACHUSETTS

WEST COAST OFFICE 690 N Sepulveda Blvd El Segundo, California (EAstgate 2-5707)

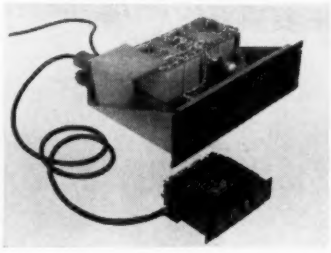
CIRCLE 79 ON READER-SERVICE CARD

OVERLOAD PROTECTOR

New Load Cell Overload Protector provides a rigid support for the cell and safely permits any load up to 10-times in excess of the rating of the cell to be transferred to the outer supports of the device. Can be used also in mechanically connecting two load cells in series, permitting extension of the rated range of the smaller cell, maintaining equal accuracy; also with cells in either tension or compression.—*Performance Measurements Co., 15301 West McNichols, Detroit 35, Mich.*

CIRCLE 192 ON READER-SERVICE CARD

DIGITAL CLOCK

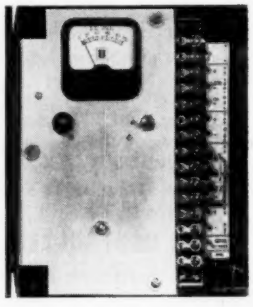


New Standard Digital Clock for process control systems utilizes sealed components and can be safely operated in areas where explosive gases are present. Besides featuring oil-filled step switches, mercury-wetted relays, and sealed switches, the clock has a highly-legible visual display. The display, composed of single-plane, in-line lamp banks, can be remotely mounted. Resetting is accomplished by pushbutton switches.—*Parabam, Inc., 13000 Yukon Ave., Hawthorne, Calif.*

CIRCLE 193 ON READER-SERVICE CARD

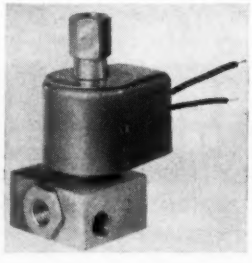
MAGNETIC AMPLIFIER

New Magnetic Amplifier can be used with any proportioning controller having an output span between 0.3 and 20 ma to provide a stepless, contactless means of electric furnace control. Relationship between input to control windings and output to the saturable reactor is linear to 5% within 30 to 70% of control current input; uniform gain over the normal working range minimizes proportional band adjustments for changes in control point setting.—*Minneapolis-Honeywell Regulator Co., Wayne and Windrim Aves., Phila. 44, Pa.*



CIRCLE 194 ON READER-SERVICE CARD

3-WAY SOLENOID VALVES

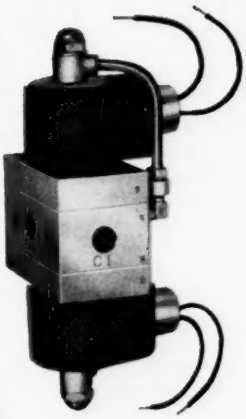


New Direct Acting 3-way Solenoid Valves, designated Bulletin 8317, feature "quick exhaust" due to an oversized ¼" dia exhaust orifice which is an integral part of the body. Bodies are brass stock with ¼" NPT connections. Resilient nylon discs provide tight seating for air, gas, water and light hydraulic oil up to 160 psig. Completely packless, they are available normally-closed, normally-open, and universal. Complete details in Bulletin 8317.—*Automatic Switch Co., Florham Park, N. J.*

CIRCLE 195 ON READER-SERVICE CARD

New 3 Position,
4 Way Solenoid Valves
Feature Dead Tight
(Poppet Type) Seating

ELIMINATE PISTON DRIFT



ASCO's new 3 position 4 way (Bulletin 8347) permits no leakage on air or liquids, assures precision positioning and positive locking of cylinder piston. Graduated (inching) or full stroke of piston may be obtained by regulating the length of time each solenoid is energized. When both solenoids are de-energized, the valve assumes a center position. All orifices are blocked, locking the cylinder piston at any point in the stroke.

Simple valve design (only moving parts are 2 solenoids and 4 diaphragms) and overall rugged construction provide millions of trouble free operations. These new valves can be mounted in any position, are available in ¼" and ⅜" pipe sizes, handle air, water and oil at pressures to 250 p.s.i. Bulletin 8347 Valves are stocked for immediate delivery.

ASCO Solenoid Valves are stocked at the Florham Park Factory, and at warehouses in Chicago and Los Angeles. **WRITE** for catalog literature on the new Bulletin 8347, and for the new ASCO Stock List and Selection Guide (Publication 506) listing the world's largest stock of solenoid valves for immediate delivery.

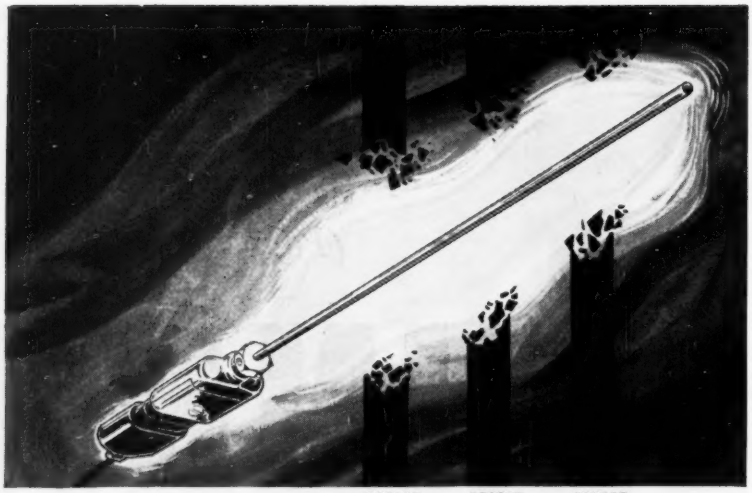
ASCO Valves

Automatic Switch Co. 52-F HANOVER RD., FLORHAM PARK, N. J., FRONTIER 7-4600

AUTOMATIC TRANSFER SWITCHES • SOLENOID VALVES • ELECTROMAGNETIC CONTROL

ASCO

CIRCLE 80 ON READER-SERVICE CARD



2000°F 3000°F 4000°F

Con-O-Pak thermocouples break the 4000°F barrier

It is now possible to measure temperatures accurately in vacuums or inert atmospheres to 4000°F and above with a single homogeneous assembly. Due to their homogeneous structure Con-O-Pak thermocouples can be formed around an exceedingly small diameter without loss of insulation resistance or dielectric strength. By combining a tantalum sheath, beryllium oxide insulation and tungsten/rhenium conductors, Continental Sensing has achieved a thermocouple accurate to 4000°F. Tungsten/rhenium thermocouples produce a relatively high EMF and are extremely sensitive to temperature change.

"Rhenium-tungsten thermocouples have been calibrated to 4000°F with an accuracy of 0.1 mv." *

For accurate temperature measurement to 3000°F in oxidizing atmospheres, Con-O-Pak provides thermocouples with platinum/platinum rhodium conductors and beryllium oxide insulation in a platinum/rhodium sheath. Calibration curves are available for all noble metal thermocouple combinations.

Con-O-Pak thermocouples cover the complete temperature range from −310°F to +4000°F. They are available in diameters from .025" to .312" and with a wide variety of junctions and terminations.

Discuss your applications with us in Booth 765 at the Instruments and Automation Conference in Chicago September 21 to 25.

*From "Calibration of Thermocouples to 4000°F" by J. C. Lachman—Instruments and Control Systems, July, 1959.

NEW! Con-O-Pak Stripper Kit for rapid hand baring of metallic sheathed thermocouple wire from .025" to .250" O.D. Complete with 6 heads and 5 extra precision ground tool bits.

Write for full information... "The Con-O-Pak Story" gives construction details and quality. Data sheets give specs and application data.

CON-PAK®

CONTINENTAL SENSING, INC.
1950 North Ruby Street, Melrose Park, Illinois

FLEXIBLE AND SHEATHED THERMOCOUPLES • THERMOCOUPLE WIRE • HEATING ELEMENTS • CONNECTORS

CIRCLE 81 ON READER-SERVICE CARD

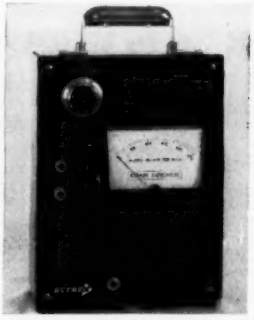
PHOTORELAY

New Model P-CE Photorelay features direct operation of relays, counters, or solenoid-actuated devices without amplification. Sensing element is a compact, rugged, moisture-resistant cadmium sulfide cell. Coil resistance of solenoid or relay should be approximately 2200-2800 ohms, maximum current 50 ma @ 115 vac.—*Berkeley/Dynamics,* 2831—*7th St., Berkeley, Calif.*

CIRCLE 196 ON READER-SERVICE CARD

STRAIN INDICATOR

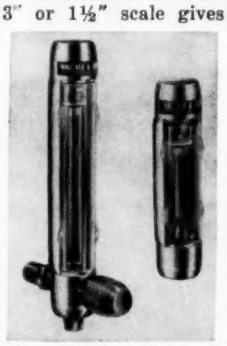
New direct-reading Strain Indicator with extremely wide range and sensitivity, Model DR-20, is for commercial strain gages and strain-gage transducers. An all-transistor instrument, it operates from four self-contained flashlight batteries. Bulletin 107 gives details.—*Bytrex Corp.,* 50 *Hunt St., Newton* 58, *Mass.*



CIRCLE 197 ON READER-SERVICE CARD

PURGE METERS

New line of Glass Tube Purge Meters with stainless-steel body and either 3" or 1½" scale gives direct reading in gph of water or scfh of air. Ranges are 0.01 to 30.0 gph or 0.12 to 125.0 scfh. Bulletin TP-1-RM gives further information.—*Wallace & Tiernan Inc., Belleville* 9, *N. J.*



CIRCLE 198 ON READER-SERVICE CARD

for your voice communications

STROMBERG-CARLSON TELEPHONE HANDSETS

MODELS FOR MANY INDUSTRIAL APPLICATIONS

No. 26: short, lightweight, sturdy. Comes with capsule-type receiver and transmitter.

No. 27: high-gain version of No. 26 handset.

No. 28: "push-to-talk" handset. Rocker bar switch; various spring combinations.

No. 29: high-gain version of No. 28 handset.

Typical applications: mobile radio • intercom systems • carrier and microwave • aircraft and railroad.

Modern handset cradle for mobile or panel use fits any Stromberg-Carlson handset.

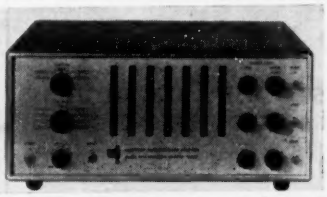
Send for Bulletins T-5005 and T-5013. Write to Telecommunication Industrial Sales, 113 Carlson Road, Rochester 3, New York.

STROMBERG-CARLSON
A DIVISION OF GENERAL DYNAMICS

CIRCLE 82 ON READER-SERVICE CARD

10-MC COUNTER-TIMERS

Three new all-solid-state counting, timing, and frequency measuring instruments, the Model 707A Transistor Frequency-Period Meter, and the Model 757A Transistor Time Interval Meter, are all-transistorized. Model

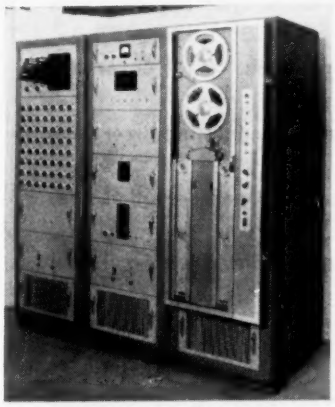


727A consists of three input channels, a special decade count-down time base, and a series of plug-in, transistorized decade counting units. Output can be on digital printers, punches, in-line Nixie readouts, etc. Measurement ranges are dc to 10 Mc for frequency; 0.1 usec to 10^7 sec for time interval; 0.1 usec for period. Accuracy is ± 1 count $\pm$oscillator stability. Sensitivity is 0.25 v rms; input impedance is 25 kohms/v.—*Computer-Measurements Co., 12970 Bradley Ave., Sylmar, Calif.*

CIRCLE 199 ON READER-SERVICE CARD

TRANSLATOR/EDITOR SYSTEM

New high-speed Translator and Editor System, developed by Consolidated Systems Corp., compresses an input of analog voltage data into a computer-compatible digital magnetic tape recording of only significant



data. Input can be direct from any number of channels, or from analog magnetic tape recording. Playback speed is a maximum of 100-times recording speed. Signal frequency is a maximum of 600 cps. Data are digitized at a max. rate of 10,000 samples /sec before the system performs its other functions. Modular system consists of three separate cabinets: digital control circuitry; buffer memory, digitizer and display; and magnetic tape unit. Solid-state, plug-in circuit boards facilitate adapting the basic system to the user's needs.—*Consolidated Electrodynamics Corp., 360 Sierra Madre Villa, Pasadena, Calif.*

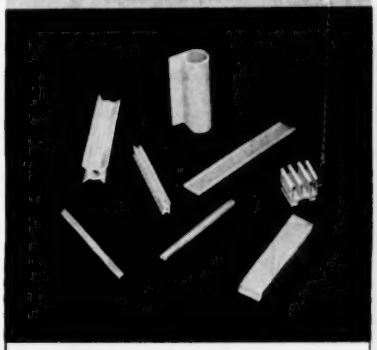
CIRCLE 200 ON READER-SERVICE CARD

NO MOLDS—NO WASTE
NO MACHINING

PF EXTRUDED TEFLON* SHAPES

Reduce Cost of Components

for electrical applications



Some of the many shapes extruded by Pennsylvania Fluorocarbon for the electrical and electronic industries include: shaped insulators, spacers, supporting channels and terminals.

These shapes offer:

- a dielectric strength from 500 to 2000 volts/mil.
- stability—no change of electrical properties with temperature (-25° C. to +250°C.) or frequency (60 cycles to 100 mc)
- zero moisture absorption
- a continuous service temperature range of 250°C.—intermittent to 300°C.

Extreme Dimensional Accuracy Assured On Any Appropriate Design

PF extruded shapes made from Teflon allow design engineers to incorporate the dielectric strength of Teflon into their products for electrical and electronic applications, economically. PF extrudes intricate Teflon shapes to extremely close tolerances, cuts them to lengths, post forms to requirements and performs any auxiliary machining steps. Molds are eliminated, there is no waste of Teflon and, frequently, no additional finishing operations are necessary. Result? Teflon components of extreme accuracy at lower cost.

Write, wire or call for a quotation on your particular Teflon component requirements, regardless of the intricacy of the shape. Shapes ranging from 2500 feet per pound to 6 feet per pound can be extruded.

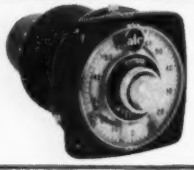
PENNSYLVANIA FLUOROCARBON CO., INC.

1115 N. 38th Street, Phila. 4, Pa.
EVergreen 6-0603 TWX: PH 252

*Du Pont registered trademark

CIRCLE 83 ON READER-SERVICE CARD

SERIES 305—Controls up to 6 individual load circuits; easily changed from "Reset" to "Non-Reset."



SERIES 306—Controls 2 separate adjustable load circuits; built-in dwell protects reversing motors.

SERIES 304—Percentage Timer; integral "On-Off" control eliminates separate switch.

SERIES 307—Revolution Counter; permits direct connection to flexible cables, differential couplings, gears, rotating shafts.

TIMERS FOR AUTOMATIC CONTROL

SPLIT SECONDS OR HOURS ACCURATE...RUGGED

Now you can order off-the-shelf timers for every industrial control application, including highly complex control functions involving hundreds of timed or sequential operations. ATC offers the widest line of standard timers, plus complete design and engineering assistance to meet special requirements. These unique features mean more dollar value from ATC timers:

Easy one-hole mounting in standard 3 3/16" cut-out. **Fully insulated ring clamp replaces screws.** **Change cycle any time with handy large knob.** **Cover slips off without disconnecting timer from service.** **One piece rolled cover has integral printed wiring schematic.**

Write now for new illustrated Condensed Catalog; contains complete specifications and performance data.

atc

AUTOMATIC TIMING & CONTROLS, INC.

KING OF PRUSSIA, PENNSYLVANIA

A SUBSIDIARY OF SAFETY INDUSTRIES, INC.

CIRCLE 84 ON READER-SERVICE CARD

PHASE ANGLE METER

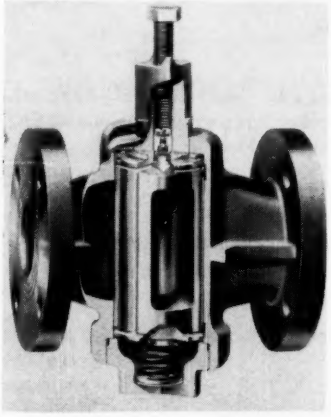
New Vectorlyzer measures phase angle with 0.02° (or 2%) accuracy and 1° full scale sensitivity. Operating principle is based on new fundamental circuit which permits unusual speed and accuracy for measuring

vector relations of alternating voltages. Specifications—Phase angle range: 0-1, 0-2, 0-4, 0-10, 0-20 and 0-180 full scale. Frequency range: 20 cps to 150 kc with binding posts, 100 kc to 500 megacycles with probe. Voltage range with binding post: 0.04, 0.1, 0.2, 0.4, 1, 2, 4, 10, 20, 40 and 100 v rms full scale; with probe, 0.4, 2 and 4 v rms full scale.—*Ad-Yu Electronics Lab., Inc.*, 249-259 *Terhune Ave., Passic, N. J.*

CIRCLE 201 ON READER-SERVICE CARD

LUBRICATED PLUG VALVE

New Lubricated Plug Valve features positive high-pressure distribution of lubricant over entire sealing surface; Teflon-floated self-freeing



plug, closely fitted to body thus preventing seepage of lubricant into line fluid; triple stem seal. Available in straight-way, 3-way, 4-way, and multiple-port types with 100-% pipe area or venturi; cast in semi-steel, steel, brass, aluminum, ni-resist, etc. Reference Book 39-5 contains details.—*Homestead Valve Mfg. Co., Box* 116, *Coraopolis, Penna.*

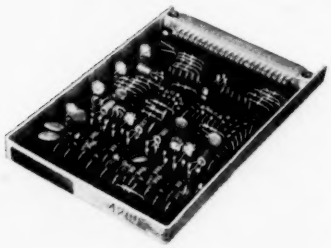
CIRCLE 202 ON READER-SERVICE CARD

an economical new line of

SYSTEM BUILDING BLOCKS

New low-speed, low-cost version of Digital's popular interchangeable plug-in building block design units

NEW 4000 SERIES



Coordinated logic packages
Operate at any speed up to 500 kc.
Directly compatible with 5 mc. line
Priced as low as $43.00 per unit

Ruggedly built for long, trouble-free service, the 4000 Series is especially suitable for process control systems and other applications where very high speeds are not required. Write for details on this new money-saving line of proven-performance DEC System Building Blocks.

digital

EQUIPMENT CORPORATION

MAYNARD, MASSACHUSETTS

WEST COAST OFFICE: 690 N. Sepulveda Blvd. El Segundo, California (EAstgate 2-5707)

CIRCLE 85 ON READER-SERVICE CARD

DIAL INDICATOR

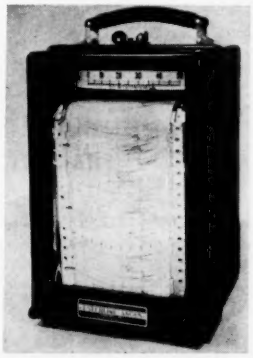
New 90K-Series Transcope Pneumatic Dial Indicators feature indicator slide replaceable by a comparable 4" strip chart 90J-Series recorder slide. The input signal transmitted to the indicator is amplified by a force-balance servo motor. This produces

indicator positioning force 150-times greater than conventional receiver elements. Options which can be added to the simple one-pointer indicator, include: indication of a second variable on a separate dial; control point detection for truly bumpless manual-to-automatic transfer; and self-contained cascade switch for pneumatic set control. Catalog 98347 contains details.—*Taylor Instrument Cos., Rochester* 1, *N. Y.*

CIRCLE 203 ON READER-SERVICE CARD

RECORDING DC MICROAMMETER

New Recording d-c Microammeter has a basic range of 0-50 μamp dc with an approximate input resistance of 200 ohms. D-c voltage ranges of



0-10, 50, and 200 mv are also included. A drift-free magnetic amplifier, powered by 120-v, 60-cps ac, is combined with a proven permanent-magnet moving-coil movement to assure high stability and long trouble-free service. Accuracy is within 2% of full scale.—*Esterline-Angus Co., Box* 596, *Indianapolis* 6, *Ind.*

CIRCLE 204 ON READER-SERVICE CARD

This is the New

TALLY

Bi-directional Paper Tape Reader

It reads paper tape rapidly and economically

Tally Series 424 Paper Tape Readers furnish a new low cost approach to rapid search and accurate punched paper tape reading. Self contained, this unique bi-directional asynchronous reader is available in both rack and console styles.

It features...

A reading rate of 60 characters per second in either direction—instantly reversible. Triggered tape feed readout. Full accountability with form C switch providing positive hole/space identification. Reads 5, 6, 7, or 8 channels without modification. Low cost, only $595 for console unit. Can be slaved to any other 60 character device.

It's ready for delivery now

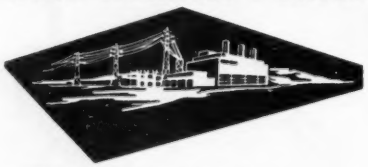
For full technical information including a 6 page folder and the name of your nearest Tally engineering representative, please write department 551.

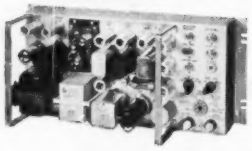
TALLY REGISTER CORPORATION

5300 14th Avenue N.W., Seattle 7, Wash.

CIRCLE 86 ON READER-SERVICE CARD

Telemeter
ANY VARIABLE
from Remote Points





MODEL 1025 Transmitter

MODEL 1090 Receiver

Accurate, Fast Acting, Frequency Type Telemeter for Transmission over Wire Lines, Microwave, and Power Line Carrier

Accurate HIGH-SPEED Continuous Telemeter for VOLTS AMPS WATTS VARS ETC.

•

Built-in Self-Calibrating Circuit

•

The Model 1025 Telemeter Transmitter converts DC mv from thermal converters, etc., to 10-30 cps which frequency modulates a built-in audio tone channel. AC 10 to 30 cps or relay outputs are also available. Receiver detects and demodulates transmitted signal, generating a DC mv for operation of recorders or indicating instruments. Up to 45 telemeters can be multiplexed.

Any communication link, including power line carrier, microwave or wire line may be used.

Over-all accuracy is 1% with a response speed of 1 second. Equipment features a built-in calibration circuit for 10% and 90% receiver check, and 10 cps and 30 cps transmitter check.

Any quantity which may be converted into a DC millivoltage or will operate a slidewire may be telemetered.

WE CAN HELP YOU
Our Applications Department is ready to assist you in your control, telemetering or communications problem. Phone DEerfield 4-3100.

Write for Technical and Application Data.

Radio Frequency
LABORATORIES, INC.
Boonton, New Jersey, U. S. A.

CIRCLE 87 ON READER-SERVICE CARD

DIRECT-ENTRY COMPUTER

New compact direct-entry Digital Computer, DE-60, in many applications will do the work of up to 20 desk calculators. Operating on standard 115-v, 60-cps power and drawing only 150 w it is completely transistorized, and requires no special cooling system. Available also for lease or rental.—*Clary Corp.*, 408 *Junipero St., San Gabriel, Calif.*

CIRCLE 205 ON READER-SERVICE CARD

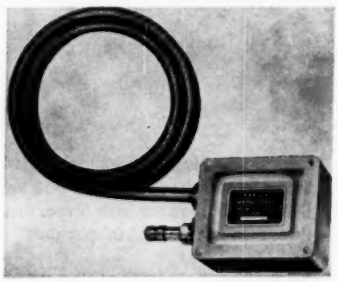
HIGH-PERFORMANCE CR TUBE

New Rayonic-type Cathode Ray Tube, 3ASP7, has high sensitivity and light output combined with a flat face (3" x 1½") and high altitude performance. Sensitivities under a typical anode voltage of 2000 v are 33 v/in vertical, and 80 v/in horizontal. It has the anode brought out separately and is rated up to 35,000 ft. Phosphors include P1, P2, P7, and P11. Tube is less than 9" long.—*Waterman Products Co.*, 2445 *Emerald St., Phila.* 25, *Pa.*

CIRCLE 206 ON READER-SERVICE CARD

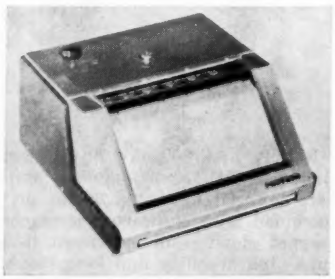
CABLE PRESSURE GUARD

New small-size Type J31 Cable Pressure Guard features adjustment range of 0 to 10 psig with a factory setting of 2 ±¼ psig; pressure response of 4 ±½ oz, and proof pressure of 30 psig. Electric rating is 0.01 amp/100 vdc. A 270,000 ohm/1 watt carbon-composition load resistor is series-connected with a snap-action switch, having palladium contacts. Waterproof enclosure is of die-cast aluminum.—*United Electric Controls Co.*, 79 *School St., Watertown* 72, *Mass.*



CIRCLE 207 ON READER-SERVICE CARD

TRANSISTORIZED OSCILLOGRAPHS



New completely-transistorized, direct-writing Oscillographs feature from two to eight channels of recording housed in one compact unit. Step attenuation provides sensitiveness of 0.002 to 10.0 v/m, and plug-in transistorized preamplifiers with octal base provide frequency response of 0 to 100 cps. Linearity is ±1.5% of full scale with a drift of less than 0.5 mm for 8 hours. Eight chart speeds are offered, and chart drives with d-c motors for airborne recording applications. Particularly suited for recording electrical phenomena of thermocouples and transducers.—*Photron Instrument Co.*, 6516 *Detroit Ave., Cleveland* 2, *Ohio.*

CIRCLE 208 ON READER-SERVICE CARD

Save $4,840 *a month*

with the Stromberg-Carlson S-C 4020

high-speed computer readout

MICROFILM PRINTER

Here's a typical example of how the Stromberg-Carlson S-C 4020 high-speed microfilm printer can save as much as $4,840 a month. Assume that an average of 2,100 graphs with 375 points each are required each month. Twenty-five engineering aids can do this work by hand at an estimated cost of $8,800 a month. One S-C 4020 high-speed printer can do the same work for $3,960... a saving of $4,840.

High-speed graph plotting is just one of the ways the S-C 4020 can save you time and money. It is ideal for all kinds of high-speed computer printing, filing and archive storage. It will record on microfilm at the rate of 15,000 plotting points or alphanumeric characters a second—either on-line or off-line. The unique CHARACTRON® shaped beam tube assures top quality reproduction of both tabular and graphic material.

Selected data, either tabular or graphic, may be projected on an accessory viewing screen only 8 seconds after film exposure. The projection unit is useful for monitoring computers.

The S-C 4020 has been proven reliable in actual service at such installations as the U.S. Navy's David Taylor Model Basin, Carderock, Md. Printers are in production right now. You can have your own printer saving hundreds of valuable engineering man-hours within six months.

LITERATURE AVAILABLE Write to Dept. A-22, Stromberg-Carlson-San Diego, 1895 Hancock Street, San Diego 12, California.

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UDTI

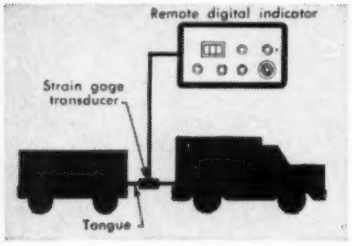
UNIVERSAL DIGITAL TRANSDUCER INDICATOR

Just ONE model from PM's family of null-balance servo type instruments

UDTI gives direct readout of weight, pressure, thrust or torque from any bonded or unbonded strain gage transducer

- Basic indicator accuracy ± 0.10% full scale
- For use with bridges from 50-2000 ohms impedance
- Self-contained calibrator
- Span control from 0.75 to 5 millivolts/volt
- Internal strain gage power supply, 6 volts DC

F.O.B. Detroit **$1550**



SAMPLE APPLICATION—Strain gage drawbar dynamometer readings are simplified with the UDTI-2. Strain gage arrangement may be either a standard pickup for measuring tension or a pair of strain gages bonded to the tongue of the towed vehicle.

Other PM instruments can measure: LOAD • THRUST • TORQUE • FLOW WEIGHT • TEMPERATURE • DISPLACEMENT VOLTAGE • PRESSURE with the highest accuracy attainable in industrial and laboratory applications

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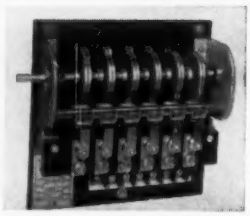
CIRCLE 89 ON READER-SERVICE CARD

ROTARY-CAM LIMIT SWITCH

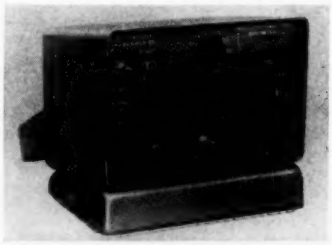


New rotary-cam Limit Switches with from 2 to 16 individual circuits, engineered to operate for millions of operations at speeds up to 300 rpm, feature large ⅜" silver contacts rated at 15 amp, ball-bearing-supported cam shaft, nylon-roller cam followers, and 2"-dia nickel-plated cams which assure accuracies to ½%.—*Eagle Signal Co.*, 202—20*th St.*, *Moline, Ill.*

CIRCLE 209 ON READER-SERVICE CARD

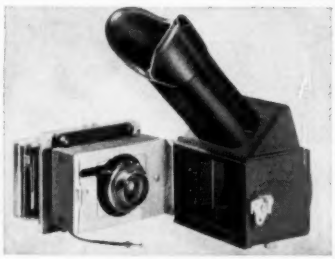
TIME BASE

New HRT-1 Time Base provides seven rates of sweep voltage for use with x-y plotters. Rates are available from 0.5 mv/sec to 50 mv/sec with 2% accuracy, which corresponds to 2sec-to-200sec for 100 mv. By rotating the panel selector to "DC Amp" the unit becomes a multi-purpose chopper stabilized d-c amplifier. Current or voltage sources deliver either an amplified current or voltage output as desired by use of proper shunts.—*Houston Instrument Corp.*, 1717 *Clay Ave.*, *Houston 3, Tex.*



CIRCLE 210 ON READER-SERVICE CARD

OSCILLOSCOPE CAMERA

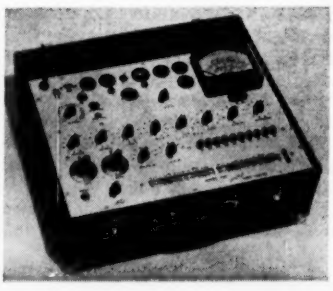


New Oscilloscope Camera, Oscillotron Model 12650, features a flat-field Wollensak f/1.9 75 mm Oscillo-Raptar lens, and is available with a Polaroid Land back. Polaroid recordings can be made either as transparencies for slide projection on Type 46 film, or as paper prints on Type 3000 speed film.—*Beattie-Coleman, Inc.*, 1000 *N. Olive St.*, *Anaheim, Calif.*

CIRCLE 211 ON READER-SERVICE CARD

TUBE TESTER

New Model 752 portable Tube Tester has high accuracy and features ease of use to reduce the possibility of operator-error in setting up specific tube tests. Specifications include; Mutual conductance ranges: 0-1500, 3000, 4000, 15,000, 30,000 micromhos. —Test voltages provided; signals: 0.25, 0.5, 1.25, 2.5 vac; plate voltages: 150 and 75 vdc; screen voltages: 130 and 56 vdc; fixed bias voltages; 0 to −40 vdc adjustable; extra negative bias supply: −40 vdc; diode test voltages: 20 vrms; 0Z4 test voltages: 287 vrms.—*Hickok Electrical Instrument Co.*, 10528 *Dupont Ave.*, *Cleveland 8, Ohio.*



CIRCLE 212 ON READER-SERVICE CARD

Now from Weston—

a new package concept for AC-DC laboratory standards

time-saving, easy-to-operate calibration consoles—accurate within .05% in D.C. .1% in A.C.

MODEL 65 DC AMMETER CALIBRATOR
MODEL 64 DC VOLTMETER CALIBRATOR
MODEL 63 AC VOLTMETER CALIBRATOR
MODEL 66 CONTROLLED TEMPERATURE BATH
MODEL 62 AC AMMETER CALIBRATOR

There's remarkable simplicity and precision in these Weston AC and DC Calibration Consoles – design simplicity that is readily apparent in clean, uncluttered panels . . . operating simplicity that now enables one operator to perform the work in ⅓ the time previously required by two skilled operators . . . with the precision of Weston engineering and craftsmanship that assures ultimate accuracy. Highly stable and readily adjustable, these consoles are truly value-packed.

Unique switching networks automatically divide scales into any number of equal parts regardless of range. It's no longer necessary to calibrate each checkpoint or set up extra equipment to obtain required outputs. Operation is reduced to four or five simple steps.

These consoles typify Weston leadership in long-term reliability and stability. All are supplied in blue-gray cabinets or ready for mounting in standard 19″ rack panels. Also available: an oil bath which accommodates up to 12 Weston Normal Standard Cells . . . maintains temperatures within .01C. Removable racks also fit baths at U.S. Bureau of Standards.

For full information, contact your local Weston representative . . . or write to Daystrom-Weston Sales Division, Newark 12, N. J. In Canada: Daystrom Ltd., 840 Caledonia Rd., Toronto 19, Ont. Export: Daystrom Int'l., 100 Empire St., Newark 12, N. J.

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Designed by Robertshaw Engineers as a controller, transmitter, or receiver-controller for process applications demanding precision, economy and serviceability combined, this new unit is packed with obvious advantages:

- Proportional Action — 0.5% to 200%
- Automatic Reset Optional
- Fully Compensated Thermal System

Easily installed without special tools, this new Robertshaw controller offers maximum convenience. Open construction permits components to be removed, replaced, recalibrated on the spot without disturbance to the rest of the unit. Minimum number of pivots for low hysteresis, added sturdiness. All adjustments quickly made by hand; no tools needed. Temperature ranges (in 200° bands) from –30 to +450° F. Pressure ranges 0-20 psi., 3-15 psi. (as receiver-controller), 0-150 psi.

For complete specifications, ask for AL-757

Robertshaw®
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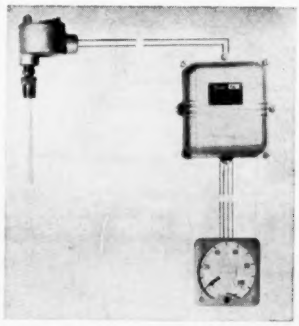
CIRCLE 91 ON READER-SERVICE CARD

LIQUID AND SOLID LEVEL

New Level-Tel 154, a continuous capacitance system, measures and indicates level changes of liquids, slurries, powders and granular solids. Consisting of a probe, detector, transmitter, and indicator, the system has



a miniature capacitance-bridge circuit housed in the probe condulet, enabling remote transmitter location. System can be checked and calibrated by depressing a test circuit button on the control panel indicator. Containing no moving parts, the system features self-cleaning Teflon probe assemblies, printed-circuit wiring and plug-ins.—*Aeronautical and Instrument Div., Robertshaw-Fulton Controls Co., Santa Ana Freeway at Euclid Ave., Anaheim, Calif.*

CIRCLE 213 ON READER-SERVICE CARD

PEAK PRESSURE GAGE

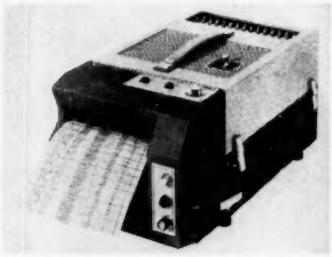
New hydraulic Peak Pressure Gage with full scale ranges of 0-4000 and 0-10,000 psig for troubleshooting and correcting hydraulic systems contains pressure pickup, amplifier, and peak

detector, followed by large meter. Meter indicates true absolute peak of pressure transients of one msec min. Gage has an output terminal on the front panel into which a standard oscilloscope or oscillograph can be attached. When used thus, it becomes a pressure amplifier with full-scale (0-4000 or 0-10,000 psi) output of 40 v and a frequency response of 0-1000 cps.—*Hydel, Inc., 223 Crescent St., Waltham 54, Mass.*

CIRCLE 214 ON READER-SERVICE CARD

RECORDING OSCILLOGRAPH

New Direct-Recording Oscillograph, Model 621 Standard, can record 8 or 14 data traces on 6"-wide paper. It ejects the record for secondary exposure and study, immediately after recording the data traces. Recording

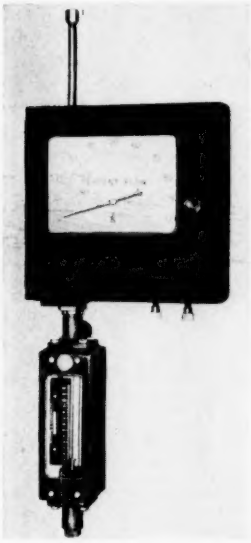


beams contact paper in full view of the operator, which allows visual check of the recording function. 3 speed ranges are available from 0.2"/min to 60"/sec. Using miniature light-beam type galvanometers, frequency responses from dc to 10,000 cps (natural response) and 6,000 cps (flat response) are available.—*Midwestern Instruments, Box* 7186, *Tulsa, Okla.*

CIRCLE 215 ON READER-SERVICE CARD

ROTAMETER TRANSMITTER

New Pneumatic Transmitting Rotameter, Model 58, features easy calibration and field recalibration; and a magnet design which provides an evenly-distributed magnetic field



without drag on the metering float. A position-balance type, the transmitter can be used with glass-tube or metal-tube rotameters. The percent scale is suitable for any calibration.—*Schutte and Koerting Co., Instrument Div., Cornwells Heights, Bucks County, Penna.*

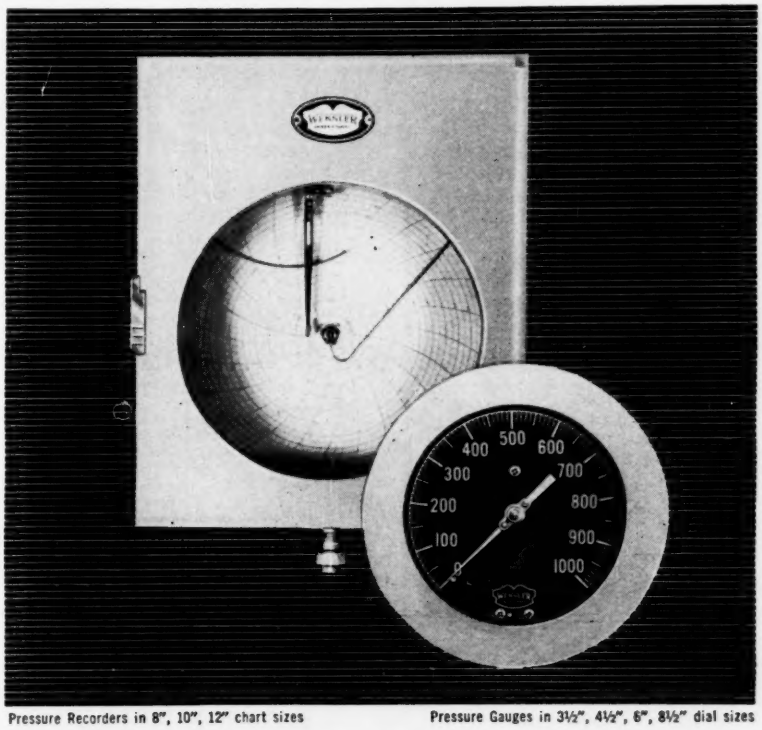
CIRCLE 216 ON READER-SERVICE CARD

WEKSLER INSTRUMENTS

SYMBOL OF QUALITY

in

Indicating and Recording Vacuum and Pressure Gauges



Pressure Recorders in 8", 10", 12" chart sizes

Pressure Gauges in 3½", 4½", 6", 8½" dial sizes

In the field of indicating and recording instruments for temperature, pressure and humidity, the name Weksler is internationally known for engineering and product excellence.

Weksler has achieved notable "firsts" in pressure gauges . . . industrial thermometers, dial thermometers, recording thermometers, recording hygrometers, bi-metal thermometers, laboratory thermometers and hydrometers.

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- *TEMPERATURE*
- *LIQUID LEVEL*
- *MERCURY SWITCHES*
- *TRANSFORMER-RELAYS*

CHECK THESE NEW PRODUCTS BY MERCOID

TYPE AP-153

New SP-DT low pressure (instrument air) control. Small in size, light in weight. Provides any of following operations: SP cut-in high; SP cut-in low; or SP-DT operation. Two operating ranges 1 to 20 and 1 to 30 psig. External adjustments, visible dial and visible circuit position. See catalog No. 860

TYPE PG

New low pressure diaphragm control for gases or air. Can be used three ways; for pressure, negative (vac.) pressure or differential pressure. External adjustments, visible dial and visible on-off circuit position. Two operating ranges, 1.0" to 30.0" and 1/2 to 5 psig. See catalog No. 860

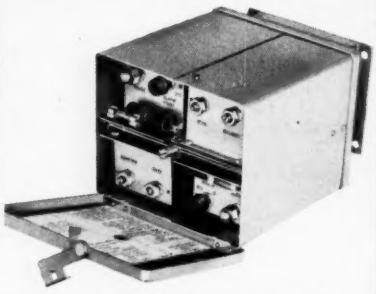
ASK FOR CATALOG NO. 860

THE MERCOID CORPORATION
4211 Belmont Ave., Chicago 41, Ill.

CIRCLE 93 ON READER-SERVICE CARD

ELECTRONIC ALARM

New, self-powered Electronic Alarm, Model R2A, that can actuate an annunciator or perform an auxiliary control function, has a built-in power supply and remotely adjustable alarm-point setting. A null-balance device, it can be used for one- or two-point alarm. The basic components for a

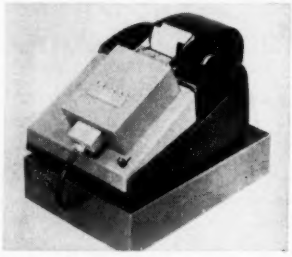


single alarm-point are mounted on two printed-circuit cards. Conversion from one- to two-point alarm, or vice versa, is accomplished by adding or removing a set of printed circuit cards. Operating from a common 0-0.5 vac signal, the alarm compares the process signal with the alarm-point signal in a difference amplifier, then is fed to the grid of a triode rectifier tube where it is compared with an a-c reference signal. When the two signals match, the tube stops conducting and the relay is de-energized until the process signal is corrected. The normally-energized relay provides "fail-safe" action.—*Swartwout Company*, 18511 *Euclid Ave., Cleveland 12, Ohio.*

CIRCLE 217 ON READER-SERVICE CARD

SCANNING PRINTER

New solenoid-actuated, self-contained Digit-Matic Scanning Printer prints data from high impedance decimal sources operating on a minimum +10-v dc input signal, scanning and



printing numbers stored in glow counter tubes, digital ohmmeters, Nixie display counters, or other electronic devices. Normal operating speed is 0.25 sec per column scanned; additional 0.27 sec is added with non-totalizing printers and 0.35 with totalizing models.—*Victor Adding Machine Co.*, 3900 *N. Rockwell St., Chicago* 18, *Ill.*

CIRCLE 218 ON READER-SERVICE CARD

WHY PAY $1000 MORE?

For a Digital Voltmeter with ±.01% Accuracy

FOR FULL FOUR-DIGIT ACCURACY IN VISUAL MEASURING JOBS — production checking, instrument calibrating, laboratory testing, receiving inspection — the NLS 481 Industrial Voltmeter is your best buy in digital instruments. Here's a precision instrument that matches — even surpasses — other dry-stepping switch meters in accuracy (±.01%), speed, reliability . . . yet sells for $1,000 to $2,000 less! High-volume production techniques and simplified circuitry enable NLS to offer the 481 at just $1,355.00, complete. Pull off the top of a 481 and check its quality construction . . . compare its performance with that of higher-cost competitive meters. Many major companies have . . . and they are now using the NLS 481 in quantities of 50 and more! Contact NLS today for full information on the NLS 481 and its companion NLS 781 Industrial Ohmmeter.

481 Specifications: Accuracy ±.01% . . . measures DC voltages from ±0.001 to ±999.9 . . . plug-in accessories permit measuring AC or low level DC voltages . . . balancing time: 1 second, average . . . input impedance: 10 megohms on all ranges . . . automatic indication of range and polarity . . . internal standard cell permits verification of calibration . . . one-package design (5¼" high, 15¼" deep for 19" rack) . . . all controls and connectors located on front panel . . . easily converted to ratiometer for analog computer readout . . . available from stock for immediate delivery . . . $1,355.00, complete.

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DEL MAR (SAN DIEGO), CALIFORNIA
NLS — The Digital Voltmeter That Works . . .
And Works . . . And Works!

CIRCLE 94 ON READER-SERVICE CARD

HIGH PRESS SOLENOID VALVE

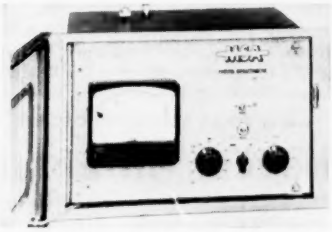
New Master-mite series of Solenoid Valves for air, water, petroleum products, coolant, oxygen, hydrogen, acetylene, etc. is made in sizes ⅛" and ¼" NPT, in both conduit and grom-

met types (see picture) with ten orifice sizes available from 3/64" through ¼". Valves can be used on pressures from vacuum to 540 psi.—*Marsh Instrument Co., 221 N. LaSalle St., Chicago 1, Ill.*

CIRCLE 219 ON READER-SERVICE CARD

PROCESS REFRACTOMETER

New Process Refractometer for automatic, continuous measurement and control of organic and inorganic liquids employs principle of measurement variations in refractive indices between the substance analyzed and

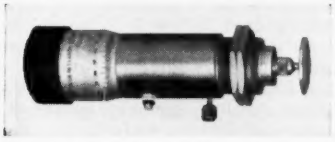


a constant standard. Wide range flexibility, easy conversion to new problems in the field, and rapid response are claimed as outstanding advantages of the instrument. Ranges are from 0-1% to 0-100%.—*Mine Safety Appliances Co., 201 N. Braddock Ave., Pittsburgh 8, Pa.*

CIRCLE 220 ON READER-SERVICE CARD

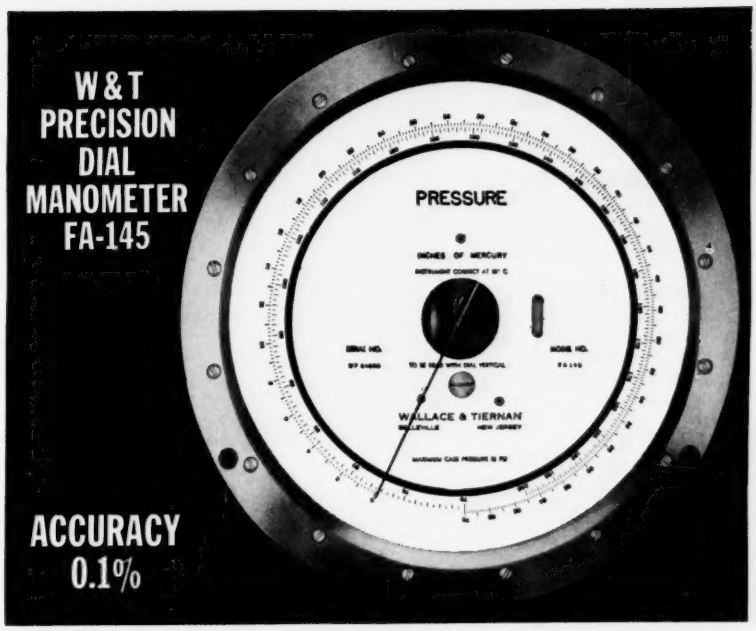
PROXIMITY TRANSDUCER

New Model PT5 Proximity Transducer, measuring small mechanical displacements from 0 to 20,000 cps in conjunction with the Photocon Dy-



nagage measuring system, features a micrometer head calibrated directly in 0.0001" Transducer can be calibrated under dynamic operating conditions.—*Photocon Research Products, 421 North Altadena Dr., Pasadena, Calif.*

CIRCLE 221 ON READER-SERVICE CARD



PRECISION PRESSURE Measurement
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Accuracy:	1/1000 of full scale
Sensitivity:	1/10,000 in *all* ranges
Ranges:	0 to 120 inches of water (min.) 0 to 300 inches of mercury (max.) Other intermediate ranges available
Scale Length:	45 inch scale in two revolutions
Dial Size:	8½ inches

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DC–15Mc (—3dB)
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.25μsec delay
50mV/cm to 50V/cm

X AMPLIFIER
DC to 2 Mc (—3dB)
.03μsec/cm to 1 sec/cm
Automatic Triggering and Voltage Selection

Model 1330
$1050

AND THIS IS NEW...
X and Y gain continuously variable and continuously calibrated to 2%

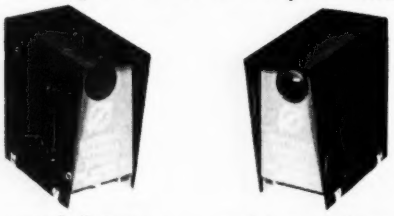
MARCONI INSTRUMENTS

111 CEDAR LANE • ENGLEWOOD, NEW JERSEY

CIRCLE 97 ON READER-SERVICE CARD

POST DECITRON ELECTRONIC PRODUCTS

MODEL K-5 — Multi-Purpose Electronic Control counts up to 1000 units per minute



POST'S K-5 control features a hermetically sealed solid state photocell which lasts indefinitely. Relay is a single pull, double throw type, DC operated for maximum reliability. No vacuum tubes to short circuit or burn out . . . little service required. Rugged enclosures are provided for both light source and receiver and input voltage may be supplied from any 115 V outlet.

The K-5 may be used as an on-off control, go-no go control, or for many other applications including safety devices, liquid level or illumination control limit switch or jam detection sensing.

Write for bulletin K-5.

Decitron

ELECTRONIC PRODUCTS DIVISION

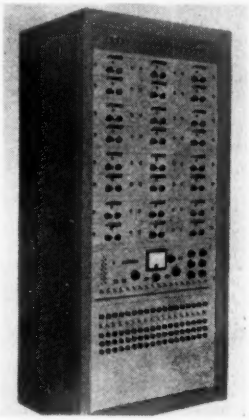
Post Machinery Co. | 159 Elliott St., Beverly, Mass.

CIRCLE 98 ON READER-SERVICE CARD

NEW INSTRUMENTS

ELECTRONIC MULTIPLIER

New MC-701 AM/FM Electronic Multiplier features a new type of FM discriminator which permits signal amplitude variation and reasonable changes in ambient temperature without consequent distortion. Non-

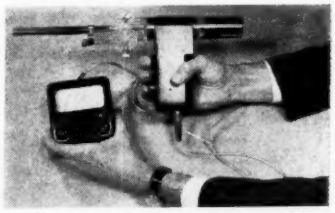


linearities are reduced to less than 0.0001 making the circuit suitable for precision multiplication over a frequency range not heretofore possible. In addition it performs division, square-root extraction, and interpolation for the generation of functions of two variables.—*Computer Systems Inc.*, 611 *Broadway, New York* 12, *N. Y.*

CIRCLE 222 ON READER-SERVICE CARD

THERMISTOR PSYCHROMETER

New portable Thermistor Psychrometer, "A+Hygrophil", has extremely rapid response which makes it ideal for air moisture determination in textile factories, paper mills, printing plants, laboratories, hospitals, etc. Using thermistor probes, the instru-



ment has three temperature scales ranging from 10° to 176°F (or —10° to 80°C). By pressing the "trigger" button the dry air temperature is read immediately; by pushing another button wet bulb temperature is read. Both readings are made in less than ten seconds and the relative air humidity is quickly read from a conventional psychromatic chart or slide rule. Spring coil motor is available for explosion-proof operation.—*Atkins Technical, Inc.*, 1276 *West Third St., Cleveland* 13, *Ohio.*

CIRCLE 223 ON READER-SERVICE CARD

STEP CONTROL SWITCH

New MS (Multi-Step) Switch is a pressure-electric switch that provides step control of electric heat-unit ventilators, fan systems, pumps, and re-

frigeration equipment. It consists of a pneumatic motor which actuates a series of electric switches in response to a pneumatic signal. Bulletin Form P-80 gives details.—*Powers Regulator Co., 3433 Oakton St., Skokie, Ill.*

CIRCLE 224 ON READER-SERVICE CARD

OSCILLOGRAM READER SYSTEM

New Oscillogram and Strip-Chart-Record Reader, the Oscar Model K, measures traces amplitudes, applies a linear or non-linear calibration, converts the data to engineering units and automatically operates a typewriter and card punch. Complete system features motorized chart drive, patchboard programming, channel and time counters, in-line decimal displays and a serial keyboard for manual data input.—*Benson-Lehner Corp., 1860 Franklin St., Santa Monica, Calif.*

CIRCLE 225 ON READER-SERVICE CARD

ELECTRONIC THERMOMETER

New Wide-Range Electronic Thermometer features easy push-button

range selection; direct readings in degrees F; ½-degree-F accuracy over the major portion of the range; 12 ranges from −425° to +800°F, and full interchangeability of probes and instruments. The recommended Type 145 temperature transducer has a platinum resistance element. Power supply can be either a self-contained "C" battery, or a-c line. Very close accuracy can then be obtained in an application such as the measurement of the temperature of liquid hydrogen.—*Trans-Sonics, Inc., Burlington, Mass.*

CIRCLE 226 ON READER-SERVICE CARD

Special Instruments

THAT TEST, MEASURE, REGULATE, SIMULATE

...for Regulating Relays, and Computer Equipment

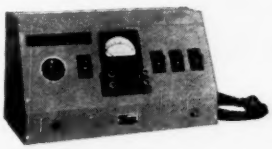
Current Flow Test Tets simplify the adjustment of single- and double-winding, YP, and polar-type relays and similar electromechanical devices. Accurate, pre-set values for "saturate," "operate," "non-operate," "hold," and "release" currents up to 750 ma can quickly be set up and repeatedly applied in any sequence. *Ask about Shallcross Types 696 and 695.*

...for Testing Welds, Bonds, Contact Resistance

Portable, wide-range Shallcross Milliohmmeters and Microhmmeters accurately measure low resistances from 0.0001 ohm to 100 ohms on linear scales. By comparing readings against pre-determined standards, defective welds, bonds, and potential failures in heavy conductors can be spotted on a "GO-NO GO" basis. Switch, relay, and circuit breaker contact resistance as well as bar-to-bar commutator resistance can also be measured. *Ask about Shallcross Low Resistance Test Sets.*

...for Measuring Kilovolts

Dozens of standard, Shallcross Kilovoltmeters and Kilovoltmeter Multipliers are available for measuring from 1 to 30 KV. Special Corona-Protected Models measure up to 200 KV. All use stable, close-tolerance Shallcross precision wirewound resistors for long-term accuracy. *Ask for details on Shallcross High Voltage Measuring Apparatus.*



...for Servicing Communications Systems

For over 25 years, Shallcross has been a key manufacturer of multi-purpose test instruments for telephone and communications system servicing. Types range from portable DB Meters, Tone Generators, and Fault Location Bridges, to elaborate instruments that measure every electrical property and simulate every normal condition usually encountered. *Ask about Shallcross Communications Servicing Instruments.*

Shallcross

OTHER SHALLCROSS PRODUCTS

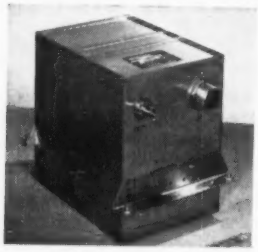
Decade Resistance Boxes • Decade Voltage Dividers • Kelvin-Wheatstone Bridges
Percent Limit Bridges • Precision Wirewound Resistors • Rotary Instrument Switches
Wheatstone Bridges • Megohm-Wheatstone Bridges • Magnetic Bridges • and dozens of custom-built instruments for laboratory, production, and field measurements

SHALLCROSS MANUFACTURING CO., 12 Preston St., Selma, N. C.

CIRCLE 99 ON READER-SERVICE CARD

DUAL Ag-Zn BATTERY

New Dual Battery in a single case, Model P46A, provides complete auxiliary power for missiles and space

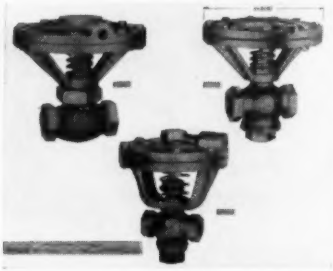


vehicles. 20-cell section delivers current of 25 amp at 28 v and a maximum of 100 amp, with a discharge time of 35 min at 25 amp. Capacity is 15 amp-hrs. Second, 4-cell section supplies 6.3-v power at 19 amp. (Discharge time is 35 min.) Capacity is 11 amp-hrs. Both sections are activated automatically by a simple electrolyte-tank-and-piston arrangement, operated by a solid propellant gas generator. Activation time is only 2.0 sec. The signal required is 4 amp at 28 v. Withstands shock to 100 g's, acceleration to 50 g's, and vibration to 5 g's.—*Cook Batteries, a subs. of Telecomputing Corp.*, 3850 *Olive St., Denver* 7, *Colo.*

CIRCLE 343 ON READER-SERVICE CARD

CONTROL VALVES

New 2020, 2030, and 2031 series Bantam valves are highly compact and diaphragm-operated. The 2020 series, which has a cast globe body with 8, 15, or 50 sq in reverse-or direct-acting operators, has three different plug trims for on-off, quick-

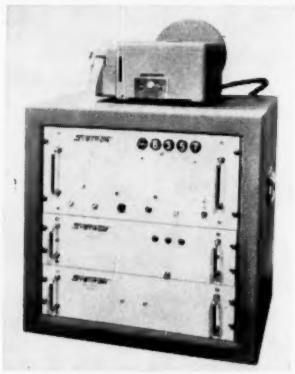


opening or moderate throttling control. It has a maximum C_v of 40.0, lift ⅝", seat areas up to 3.1 sq in and connections ¼" to 2" NPT. The 2030 series is similar except for its reverse-acting plug. The 2031 series is a three-way valve for diverting, blending or selecting. It has a cast bronze body and operators with 8, 15, or 50 sq-in diaphragms. Connections range is ½" to 2" NPT.—*George W. Dahl Co., Inc.*, 86 *Tupelo St., Bristol, R. I.*

CIRCLE 344 ON READER-SERVICE CARD

HIGH SPEED DATA PROCESSOR

New single channel Analog-to-Digital Conversion System, Model 161, provides a punch paper tape proc-

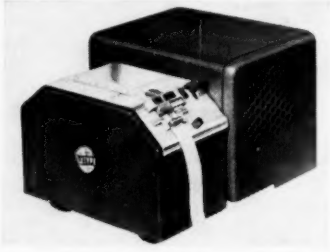


essed in binary coded decimal form for use with most special-purpose digital computers. The system measures d-c voltages from 3 μv to 1000 v with an accuracy of ±0.05% and at a recording speed of 10/sec.—*Systron Corp.*, 950 *Galindo St., Concord, Calif.*

CIRCLE 227 ON READER-SERVICE CARD

MIN TAPE READER SET

New Model 28 Miniaturized LXD Tape Reader features facilities for sequential (serial) output, 100-word/



min transmission, and low power requirements. Components of the set, such as the transmitter-distributor portion, are available separately (without motor, base or cover) for integration with systems equipment. —*Teletype Corp., Dept. SP-8*, 4100 *Fullerton Ave., Chicago* 39, *Ill.*

CIRCLE 228 ON READER-SERVICE CARD

INTERFERENCE FILTER

New colorless, non-absorbing FS Multi-Layer Interference Filter which removes completely the ultraviolet and reflects the infrared, transmits about 90% in the visible from 425 mu to 700 mu and has a sharp cut-off beginning at 700 mu, reflecting the longer wave lengths. The half transmission point is at 412 mu on the short side and 725 mu on the long side.—*Fish-Schurman Corp.*, 70 *Portman Rd., New Rochelle, N. Y.*

CIRCLE 229 ON READER-SERVICE CARD

FROM THE DESIGN LABORATORIES OF Gyra

Precise control of voltages

Superior voltage regulation at competitive prices incorporating a new method of control, the result of six years of design effort by the staff of Gyra Electronics Corporation. All designs incorporate the Bucknam circuit for superior long-term regulation. Tubes are accessible from the rear with removing the instrument from a standard relay rack. Cabinet panels are available at extra cost.

MODEL V-200

MODEL V-200. 0 to −2000 volts, continuously variable, with up to 5 MA output in a single chassis.

MODEL V-201. +300 to +2000 volts, continuously variable with 5 MA output.

MODEL V-202. 0 to +2000 volts, continuously variable, with up to 5 MA output.

MODEL V-206. Dual 0 to −2000 volts, continuously variable, 5 MA output. Identical to having two Model V-202 units in single 3½ inch chassis.

MODEL V-104. 0 to +500 volts, continuously variable, 1 MA output. Specially designed for fission chamber control. Optional design allows 0 to +800 volts, 1 MA.

MODEL V-106. +300 to +800 volts, and 0 to −100 volts, continuously variable, 1 MA output. Specially designed and dual polarity unit for compensated ion chambers.

MODEL V-301. +500 to +300 volts, continuously variable, with 5 MA output.

Gyra Electronics also offers a line of fixed 300 volt power supplies with 175 MA output. Stability: 1 part in 10^4 without oven; ±3 parts in 10^5 with oven. Impedance: 1 ohm with meter, 0.001 ohm without meter. Four models available, write for prices and literature.

OUTPUT CHARACTERISTICS	V-104	V-106	V-200	V-201	V-202	V-206	V-301
Impedance, ohms	0.1	0.1	0.1	0.1	0.1	0.1	0.1
Ripple voltage, rms	5MV	5MV	5MV	5MV	5MV	5MV	7MV
Output change with 1 volt line change	0.01%	Note A	500μv	10^{-6}	100μv	500μv	10^{-6}
60 cycle sola regulation	Yes	Yes	No	No	Yes	Yes	No
INPUT REQUIREMENTS							
Line Voltage	100 to 130		105 to 125		100 to 130		105-125
Power consumed, watts	60	60	60	60	60	60	70
PRICES, F.O.B, LaGrange, Ill.	$500.	$650.	$325.	$325.	$650.	$525.	$400.

Note A: Less than 5% instability (dvdp less than 1 mv per second)

Gyra ELECTRONICS CORPORATION

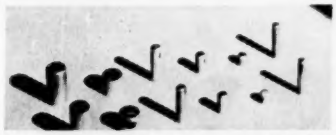
P. O. BOX 184 • LAGRANGE, ILL. • FLeetwood 4-4644

SALES REPRESENTATIVE: ROBT. M. LUNDGREN & CO. • P.O. Box 201 • Batavia, Ill. • TRemont 9-3486

CIRCLE 101 ON READER-SERVICE CARD

THERMOELECTRIC GENERATOR ELEMENTS

New Thermoelectric Generator Elements TEG#2P (positive tape) and TEG #2N (negative type) made of lead telluride deliver over-all efficiencies of 6% or more. Calculated

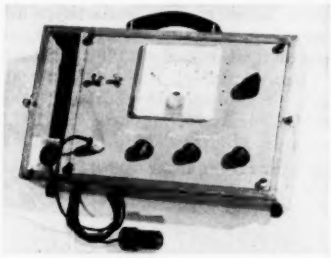


thermal efficiency at matched load conditions for the elements under a temperature differential of 1000°F is 7.85%. Available in six standard sizes, they are supplied with prefinished hot junction surfaces and pre-tinned cold junction surfaces; they can be assembled directly into test fixtures.—*Minnesota Mining and Mfg. Co.*, 900 *Bush Ave., St. Paul* 6, *Minn.*

CIRCLE 230 ON READER-SERVICE CARD

RADIATION DETECTOR

New redesigned Stoll-Hardy Radiometer, Model HL4, a total radiation detector used for measuring the temperature of surfaces of essentially



unit emissivity in the range of 100°C above and below ambient, features the calibration controls on the front panel in the form of recessed screwdriver adjustments.—*Williamson Development Co., Inc.*, 317 *Main St., West Concord, Mass.*

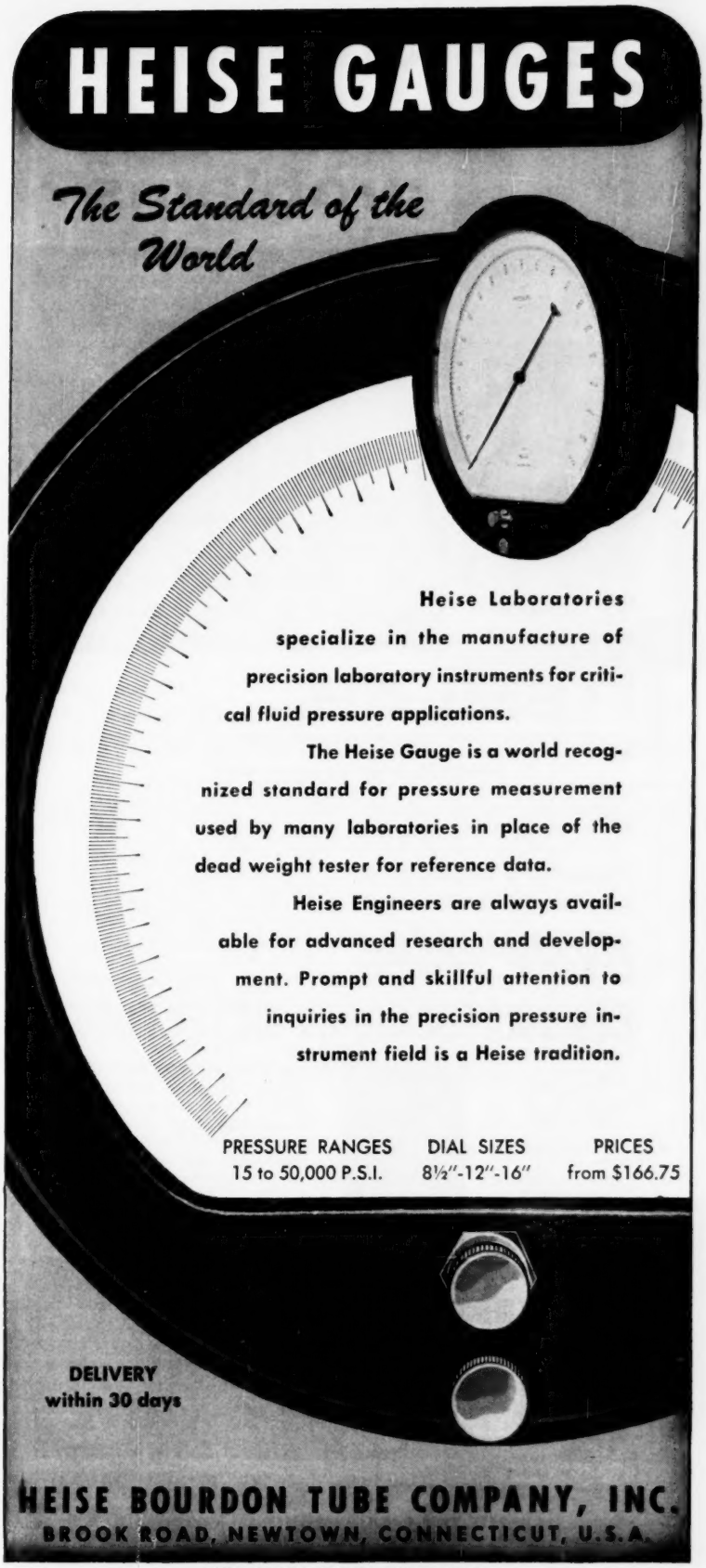
CIRCLE 231 ON READER-SERVICE CARD

TAPE SPLICER

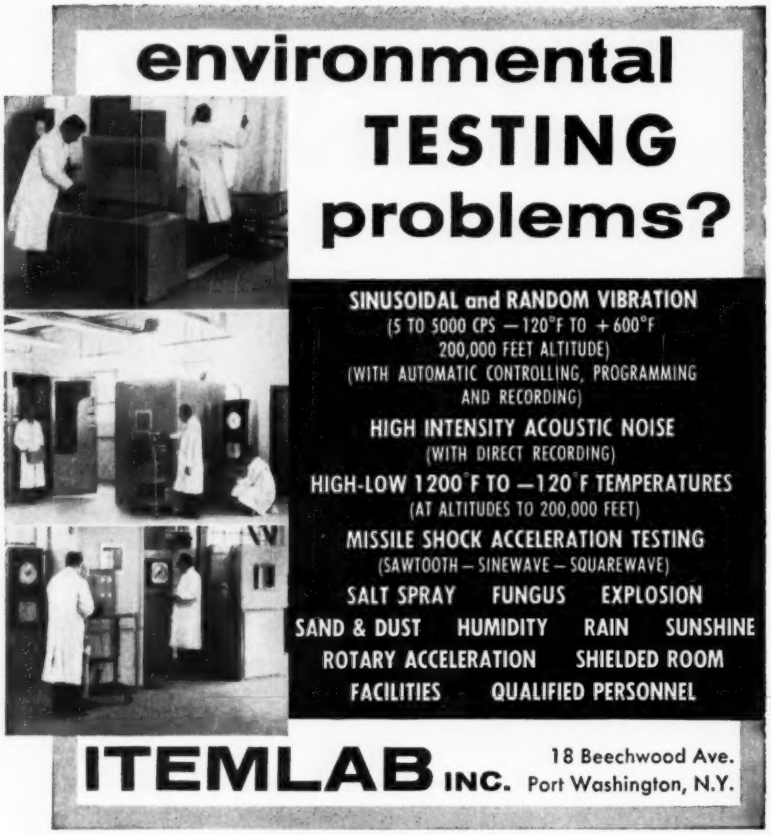
New Tape Splicer secures precise overlapping, or flush splices, on damaged or broken tapes. The kit consists of a small metal block with a

row of small pins which fit into the feed holes of all standard tapes, a supply of pre-punched pressure-sensitive tapes for flush splicing, a tube of cement for overlap splices, and a rubber pressure pad.—*Unicorn Div., Computer Measurements Co.*, 12970 *Bradley Ave., Sylmar, Calif.*

CIRCLE 232 ON READER-SERVICE CARD


HEISE GAUGES
The Standard of the World
Heise Laboratories specialize in the manufacture of precision laboratory instruments for critical fluid pressure applications.
The Heise Gauge is a world recognized standard for pressure measurement used by many laboratories in place of the dead weight tester for reference data.
Heise Engineers are always available for advanced research and development. Prompt and skillful attention to inquiries in the precision pressure instrument field is a Heise tradition.
PRESSURE RANGES
15 to 50,000 P.S.I.
DIAL SIZES
8½"-12"-16"
PRICES
from $166.75
DELIVERY
within 30 days
HEISE BOURDON TUBE COMPANY, INC.
BROOK ROAD, NEWTOWN, CONNECTICUT, U.S.A.

CIRCLE 102 ON READER-SERVICE CARD



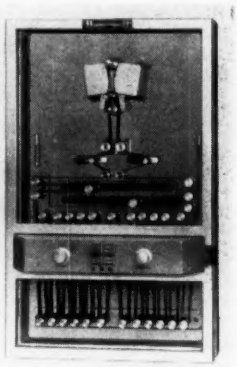
CIRCLE 103 ON READER-SERVICE CARD

Plumber's Nightmare
or Chemist's Dream?
GOW-MAC
CHROMATOGRAPHY DETECTORS
OIL BATH
Call or write for bulletins on
GOW-MAC . . .
Hot-wire filaments in matched pairs.
Temperature Regulated Cells, ON STREAM and chromatography.
Pancake DC Power Supplies.
Portable GAS MASTERS.
Gas Blenders for forming gas.
Helium Purity Analyzer Recorders.
SPECIAL BENDS
SEMI-BALL METAL JOINTS
— HAVE IMPROVED PERFORMANCE because of lower pneumatic noise and easier installation from GOW-MAC (special sketch) SSK T/C cell assemblies with special gas flow connections for individual or O.E.M. designs.
— LOWER LIMITS OF DETECTABILITY from these specifications combined with new GOW-MAC solid state, special Pancake DC Power Supply with microdial zero adjust.
— LOW-COST RELIABLE GOW-MAC hot wire T/C units are products of continuous research.
Please address inquiries to Department IA
GOW-MAC
INSTRUMENT COMPANY
100 Kings Rd., Madison, New Jersey, U.S.A.
Telephone FRontier 7-3450
► 1935-1960 Our Twenty-fifth Anniversary

CIRCLE 104 ON READER-SERVICE CARD

TAPE HANDLERS

New continuous-loop Transports, Series 3190, handling magnetic tape lengths up to 35, 80 and 100 ft and up to 2" width, are for detailed analysis programs such as those in conjunction with analog computers and with wave analyzers to examine the full frequency spectrum recorded over



varying reel time periods. Features include a loop mechanisms having isolated tape path under the multi-rack record and playback heads for high-precision low-flutter performance; up to nine tape speeds; dual-tension sensors; slide mounting; and integral power supply. A tape loop adapter for the Series 3170 transports is also available, with details contained in Bulletin DS 3210.—*Minneapolis-Honeywell Regulator Co.*, 10721 *Hanna St., Beltsville, Md.*

CIRCLE 233 ON READER-SERVICE CARD

ROTARY SWITCH

New line of Rotary Switching Devices for missiles and aircraft systems, used to sequence or switch circuitry as a function of time or shaft position, eliminates need for precise cam-like mechanical arrangements normally used in conjunction with micro-switches. They permit high speed switching rates (up to 1000-

rpm shaft speed) have mechanical accuracy of segmentation of ±1%, starting and running torque of 0.1 in-oz, and current capacity of 50 ma at 28-v/brush. Advance Technical Data Sheet gives details.—*Kearfott Co., Inc.*, 1500 *Main Ave., Clifton, N. J.*

CIRCLE 234 ON READER-SERVICE CARD

SCIENTIFIC COMPUTER

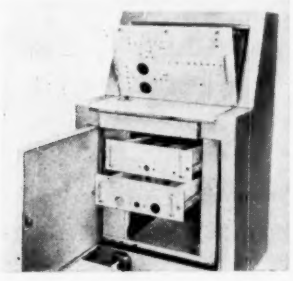
New fully-transistorized IBM 1620 Data Processing System, a small but powerful stored-program computer, has solid-state components and ad-

vanced computer circuits which provide reliable, high-speed operation. Consisting of two modular units, a Central Processing Unit and a Paper Tape Reader and Punch, it incorporates many design features formerly found only in much larger computers. These includes 20,000 digits of magnetic core storage, a variable field length memory, and paper tape and electric typewriter input and output. *—IBM Data Processing Div.,* 112 *East Post Rd., White Plains, N. Y.*

CIRCLE 235 ON READER-SERVICE CARD

STANDARD CONSOLES

New standardized Control Consoles formed of either aluminum, magnesium or stainless steel, permit



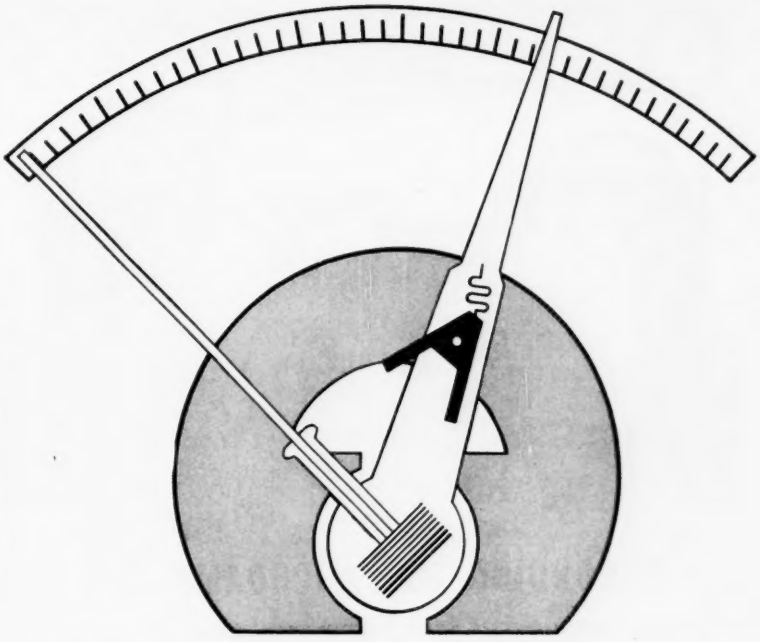
proper arrangement of instruments and controls for time-saving and error-free operation. Consoles are engineered for production from standard tools and dies, and feature modular extension possibilities.—*Falstrom Co.,* 302 *Falstrom Court, Passiac, N. J.*

CIRCLE 236 ON READER-SERVICE CARD

GAS DENSITY DETECTOR

New Gas Density Detector converts chromatographic peak area directly into weight per cent if the molecular weight of the components is known. If the molecular weights are not known they can be determined. Measurements made by the Gas Density Detector are closely comparable to those from thermal conductivity cells. Precision and accuracy are excellent. Nitrogen eluting gas is used.—*Gow-Mac Instrument Co.,* 100 *Kings Rd., Madison, N. J.*

CIRCLE 237 ON READER-SERVICE CARD



newest principle
...for monitoring
...regulating
...controlling

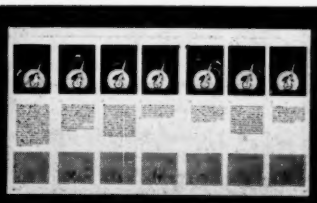
new CRMR meter-relay offers continuous indication, continuous control utilizing the simplest control system ever

The new CRMR (short for Continuous-Reading Meter-Relay) permits you to perform minor miracles in simplifying control circuitry. A new toggle-contact principle gives full-scale indication at all times with immediate, non-cyclic control response. An unrestrained D'Arsonval movement gives high sensitivity and versatility to measure any electrically-measureable variable.

The entire system consists of the CRMR and a load relay. Interrupters are eliminated. So is their associated circuitry. Reset is instantaneous and automatic.

Because of the exclusive API booster coil, contacting action is fast, firm and virtually without "dead zone." Control performance is uncompromisingly reliable.

THE COMPLETE STORY in pictures . . . a clear, graphic presentation of the CRMR and associated circuitry is provided in Bulletin S-2.
SEND FOR YOUR COPY



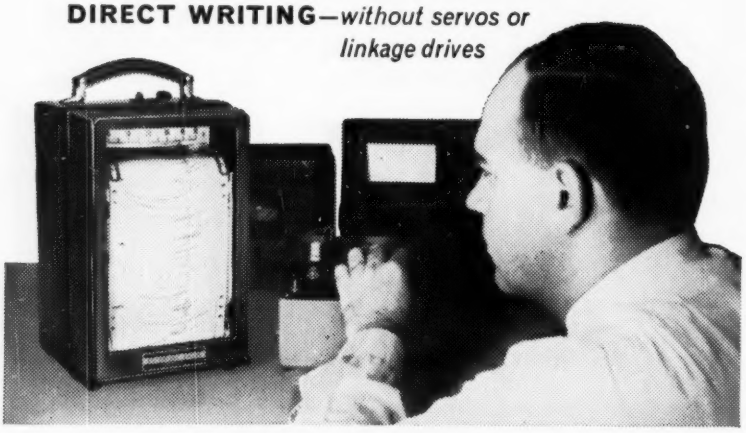
api **ASSEMBLY PRODUCTS, INC.**
Chesterland 10, Ohio

O.A. 8111

CIRCLE 105 ON READER-SERVICE CARD

DIRECT USE—*without auxiliary amplification*

DIRECT WRITING—*without servos or linkage drives*



RECORDING D.C. MICROAMMETER

Here's the recording instrument of a thousand-and-one uses in every field of research and production.

Ranges: 0 to 50 microamperes with approximately 200 ohms input resistance. Also 0-10/50/200 millivolts D.C.

Power Supply: 120 volts, 60 cycles.

Response: 1 second, independent of external circuit resistance.

It's ruggedly built for continuously reliable results in rough use. It's quickly and easily set up. Send for Catalog Section No. 41.

The Esterline-Angus Company

No. 1 in fine Graphic Instruments for more than 50 years.

DEPT. G, P. O. BOX 596, INDIANAPOLIS 6, INDIANA

CIRCLE 106 ON READER-SERVICE CARD

EXTREME LOW TEMPERATURES INTRODUCES CHALLENGING PROBLEMS FOR CREATIVE ENGINEERS — LOW TEMPERATURE PROCESSING INC.

INSTRUMENT ENGINEER

Central Engineering Department seeks ME or ChE to specify instruments and safety valves for entire job, review vendors' proposals and participate in vendor selection. Will also coordinate instrumentation among Project Engineers, customers and other design groups. Desire 4-6 years' instrument engineering. Knowledge of prominent makes and manufacturers of pneumatic and electrical instruments required.

Air Products **OFFERS:**

- **Outstanding corporate growth record thus creating new opportunities for individual growth.**
- **Substantial backlog of orders and future prospects present advancement opportunity.**
- **Broad market diversification including basic steel producers, chemical, petrochemical, refinery, natural gas and defense customers.**
- **Company develops, designs, manufactures, constructs and operates its own equipment.**
- **Location: suburban living yet near Philadelphia and New York for metropolitan advantages. Excellent school and recreational facilities.**
- **Liberal benefit program including tuition refund.**
- **Relocation paid. Well evaluated salary program.**

Air Products ...INCORPORATED

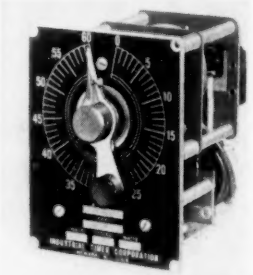
Please send resume to E. J. Strobel, Technical Personnel Manager, Dept. 534

P.O. BOX 538, ALLENTOWN, PA.

NEW INSTRUMENTS

INTERVAL TIMER

New Panel Mounting Interval Timer, Series PAF, available in timing ranges from 1 sec to 3 hours has a load rating of 15 amp at 115/60,

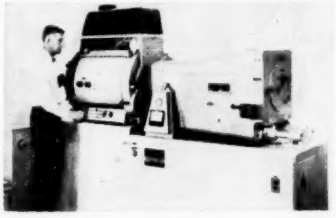


non-inductive. It automatically resets at the end of its preset time cycle (reset time is less than 0.02 sec) over the complete time scale, regardless of time cycle. Repeat accuracy is ±3 to 5 msec over a complete 1-sec scale.—*Industrial Timer Corp.*, 1407 *McCarter Highway, Newark* 4, *N. J.*

CIRCLE 238 ON READER-SERVICE CARD

ARC IMAGING FURNACE

New ADL-Strong Arc Imaging Furnace, providing a completely integrated system for a non-contaminating heat source in laboratories working in the 2000° to 4000°K region, furnishes heat fluxes corresponding



to equivalent black-body temperatures of 3950°K and 3660°K, in the center of the sample zone and an average, respectively. In principle, an arc is struck between two carbons; the tail flame plasma is concentrated by a ring of impinging air jets and stirred by a magnetic field surrounding the anode.—*Arthur D. Little, Inc.*, 20 *Acorn Park, Cambridge* 40, *Mass.*

CIRCLE 239 ON READER-SERVICE CARD

PHOTOELECTRIC PICKUPS

New Miniature Electronic Controls permit electric eye counting and controlling units to be used in processing, printing, machine controls, etc. Overall size of the photo unit and light units is $1\frac{13}{16}$" x $1\frac{5}{16}$" and $\frac{11}{16}$" dia. Units can be mounted directly on ¼" pipe, which is also used as conduit.—*Photomation, Inc.*, 96 *S. Washington Ave., Bergenfield, N. J.*

CIRCLE 240 ON READER-SERVICE CARD

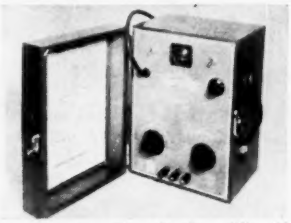
PRESSURE REGULATOR

New KP-4, an external-pilot-operated steam-pressure Reducing Valve, features an AISI-Type 440C stainless-steel-ball inner valve which closes against a monel seat ring to withstand the wire-drawing effects of steam indefinitely; a large main-valve diaphragm of stainless steel; and a control spring located entirely outside of the path of steam flow. Sizes are ¾" to 4" with screwed ends up to 3" and flanged bodies from 1¼" to 4".—*Klipfel Valves, Inc.*, 1075 *Lincoln Ave., Hamilton, Ohio.*

CIRCLE 241 ON READER-SERVICE CARD

CONDUCTIVITY BRIDGE

New Type RC-16B2 Bridge is a general purpose instrument for laboratory determination of electrolytic conductivity and also for resistance



measurements. Its dual calibrations permit readings of resistance over a range from 0.2 to 2,500,000 ohms, and of conductance from 0.4 to 5,000,000 micromhos. Unit incorporates a VT oscillator for supplying 1000-cps voltage to the bridge circuit; a vacuum tube amplifier to amplify the bridge output; and an electron-ray tube used as a null-indicator.—*Industrial Instruments Inc., 89 Commerce Rd., Cedar Grove, N. J.*

CIRCLE 242 ON READER-SERVICE CARD

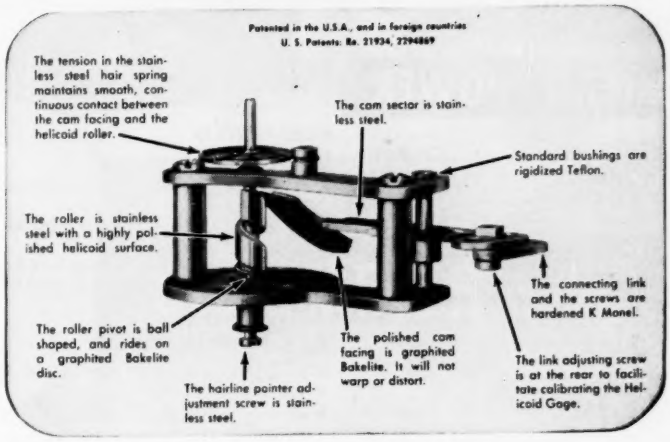
LOW-COST LEAK STANDARD

New low-cost Leak Standard for calibrating and checking operation of halogen-sensitive leak detectors, made as a small portable unit weighing about three pounds, provides an ad-

justable reference leak of known rate. In operation, it releases refrigerant gas through a tiny capillary tube at manually-controlled rates (indicated on a circular dial), ranging up to about 3 oz a year. Intended for use with Types H, H-1, H-2, H-3, H-5 and H-6 leak detectors.—*General Electric Co., Schenectady 5, N. Y.*

CIRCLE 243 ON READER-SERVICE CARD

ACCO Helicoid Gage U.S.A.


Patented in the U.S.A., and in foreign countries
U. S. Patents: Re. 21934, 2794869
The tension in the stainless steel hair spring maintains smooth, continuous contact between the cam facing and the helicoid roller.
The cam sector is stainless steel.
Standard bushings are rigidized Teflon.
The roller is stainless steel with a highly polished helicoid surface.
The connecting link and the screws are hardened K Monel.
The roller pivot is ball shaped, and rides on a graphited Bakelite disc.
The polished cam facing is graphited Bakelite. It will not warp or distort.
The link adjusting screw is at the rear to facilitate calibrating the Helicoid Gage.
The hairline pointer adjustment screw is stainless steel.

Exclusive Helicoid movement provides... *Sustained Accuracy... on the toughest jobs*

• Helicoid Gages have no gears, no teeth, reducing wear to an absolute minimum. No danger of fouling, either—rolling action of cam facing keeps contact surface clean. Helicoid Gages have been tested through 75,000,000 cycles, with virtually no wear or loss of accuracy, while conventional geared gages became useless after 500,000 cycles.

Helicoid Gages give *sustained* accuracy even when subjected to violent pressure pulsations or mechanical vibrations. Pointer can be set externally, without removing glass, and cannot be jarred out of position. Dial faces are easy to read, won't corrode or chip. A full range of Helicoid Gages is available for any application. Next time, specify Helicoid—the gage that *stays* accurate.

Bourdon Tubes won't Stretch, Leak, or Crack

Helicoid Bourdon tubes are made from seamless tubing, and are designed for maximum torque and minimum stress. At the factory, each tube is individually tested, overpressured, and stress relieved. Four materials—alloy steel, K Monel, stainless steel, and phosphor bronze—are available to meet applications ranging from tap water to almost any acid.

NEW! Solid-Front Safety Case Gives Added Protection

The new Helicoid solid-front case diverts the force of a burst in a backward direction, away from the operator. The force escapes by deforming, though not detaching, the back cover plate. Helicoid Gages are also available in phenol, acaloy flanged, acaloy flangeless, polished flangeless, round flush, polished flush ring, and square flush cases.

WRITE for details **Ask for Catalog DH-65**

HELICOID GAGES

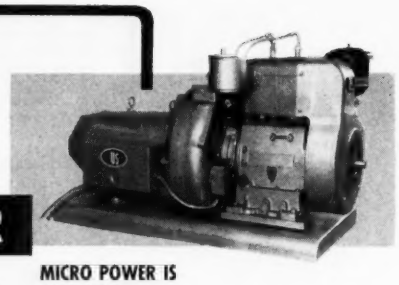
ACCO

Helicoid Gage Division • American Chain & Cable Company, Inc.
929-B Connecticut Ave., Bridgeport 2, Conn.

CIRCLE 108 ON READER-SERVICE CARD

DOUGLAS AIRCRAFT
TULSA DIVISION . . .
assures effectiveness of its protective boiler flame controls with . . .

MICRO POWER



In plants like Douglas Aircraft Company, Inc., in Tulsa, Oklahoma, where a continual supply of steam is vital to production processes, every precaution must be taken to assure against the hazards of boiler flame-out. To safely regulate its burners in the event of flame-out, the company utilizes highly sensitive electric controls. Since these flame failure controls *are* electric and must depend on a constant, unwavering power supply for successful operation, this is achieved with MICRO POWER.

At Douglas Aircraft in Tulsa, Micro Power serves as the dependable rear guard to the boiler room. It provides a constant source of steady, independent electrical power as required by the safety controls, thereby eliminating voltage fluctuations and protecting against power failure.

MICRO POWER IS ALSO USED . . .

- on microwave systems for communications, for remote control, for telemetering.
- for refinery and chemical process indication and control.
- by public utilities through microwave for protective relaying, telemetering and load distribution.

MICRO POWER PROVIDES . . .

- a constant uninterrupted source of electric power.
- voltage and frequency at usable value during transfers between motor and engine.
- stable voltage output.
- flywheel starting — no storage batteries.
- electrical isolation from commercial source — voltage dips, peaks and breaks do not affect microwave equipment, no transfer switch.

For complete information on this and other Micro Power applications, write . . .

UNITED STATES MOTORS CORPORATION
102 W. 5th Avenue • Oshkosh, Wisconsin

CIRCLE 109 ON READER-SERVICE CARD

Model MM-2

PRANDTL

MICROMANOMETER

measures small pressure differences with an accuracy of 0.000006 of 1 psi over a range of 2″

This 3 channel instrument is temperature calibrated and can be used as a secondary standard. Write for Bulletin No. 17.

FLOW CORPORATION
85 MYSTIC STREET
ARLINGTON 74, MASS.

CIRCLE 110 ON READER-SERVICE CARD

HEUER

IMPROVES STOPWATCH LEGIBILITY BY 85%

New Central Register design improves legibility over all other timers. Heuer Century Decimal Timer

Heuer's exclusive features:

1. Doubled register capacity—red center hand registers up to 60 minutes.
2. Smart black nonreflecting finish—twice as hard as standard chrome.
3. Incabloc jeweled shock-protection and unbreakable mainspring.

Remarkably low **$25.00** **Ref. 33.213**

Timerboards from $10

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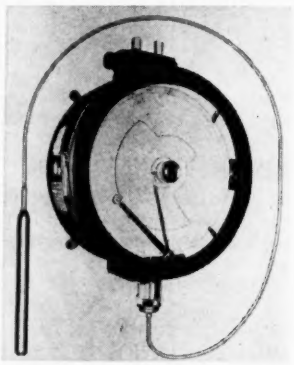
441 LEXINGTON AVENUE, NEW YORK 17, N. Y.

CIRCLE 111 ON READER-SERVICE CARD

NEW INSTRUMENTS

TEMP-PROGRAM CONTROLLER

New recording Pneumatic Temperature Program Controller, Model RCA, is available in any of ten optional temperature ranges between the extremes of −30° and +1100°F.

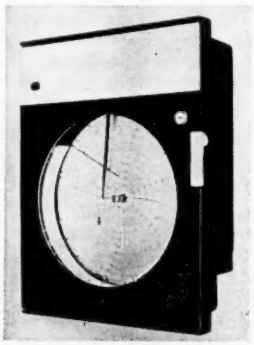


Using a plastic which can be pre-cut at the factory or easily cut in the field to the correct program, it has a built in fail-safe provision in its design. Elements of the same scale range are interchangeable, regardless of bulb type.—*Partlow Corp.*, 530 *Campion Rd., New Hartford (Utica), N. Y.*

CIRCLE 244 ON READER-SERVICE CARD

12" RECORDER

Newly redesigned 12″ Multiple Recorder for temperature or pressure features a modernized exterior, wall or panel mounting, and improved visibility of the recording chart. Up



to four recording pens can be provided. Filled-system thermometer elements can measure temperatures from −300 to +1200°F, (fills include mercury, vapor, gas, and organic liquid), and pressures from 30″ Hg vacuum to 25,000 psig can be recorded.—*U. S. Gauge Div. of American Machine & Metals, Inc., Sellersville, Penna.*

CIRCLE 245 ON READER-SERVICE CARD

PROPORTIONING PUMP

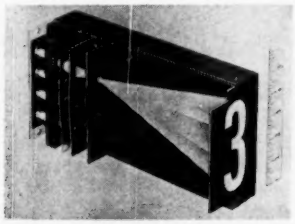
New Model CPQ-3-3-2-1-1 Positive Displacement Pump is equipped with a multi-head assembly in which each pump can be adjusted manually to establish feed ratio. The overall out-

put is changed pneumatically to the variable speed drive from a remote panel board. A reciprocating piston within the pump forces oil to move a diaphragm forward and to return. The piston does not incorporate a stuffing box as only oil is automatically replaced by a vacuum compensator valve.—*Lapp Insulator Co., Inc.*, 107 *Hall St., LeRoy, N. Y.*

CIRCLE 246 ON READER-SERVICE CARD

PROJECTION-TYPE READOUT

New Series 80,000 In-Line Display has 3¾"-high by 2"-wide characters and can be viewed from more than 100 ft away. Features include a three-

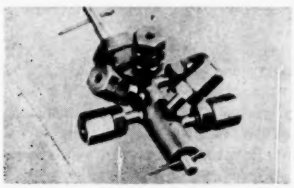


lens optical system, a body case made of aluminum, no moving parts, etc. —*Industrial Electronics Engineers, Inc.*, 5528 *Vineland Ave., North Hollywood, Calif.*

CIRCLE 247 ON READER-SERVICE CARD

MULTI-PORT VALVES

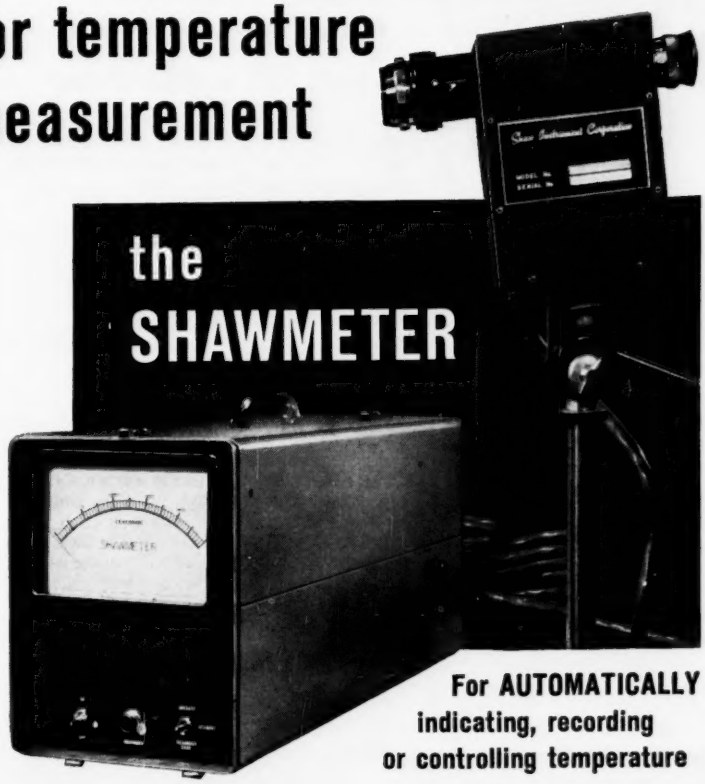
Two new multi-port linear O-ring Valves, Models 206 and 208, for gas-chromatograph column switching and similar uses, have six and eight ports,



respectively, each having two positions. Tandem operation may be obtained using plunger couplers. Both models are manually operated but may be supplied with cylinder, diaphram, or motor operators. Standard connections are for ⅛" OD tubing.—*Loe Engineering Co.*, 237 *N. Fair Oaks, Pasadena, Calif.*

CIRCLE 248 ON READER-SERVICE CARD

A new type instrument for temperature measurement



For AUTOMATICALLY indicating, recording or controlling temperature

NOT a radiation pyrometer

NOT an optical pyrometer

Employing a unique principle that eliminates the shortcomings of previous instruments, the Shawmeter provides an easy, continuous, automatic method of measuring the temperature of flowing molten metal, moving objects in a kiln or furnace, lamp filaments, induction heating coils or other high temperature objects.

The Shawmeter consists of two units: the Sensing Head which responds to the color of the object being measured; and the Control Unit, which converts the information into a direct-reading linear temperature measurement. The Sensing Head may be as close to the object as a few inches, or it may be several hundred feet away. The Control Unit may be placed wherever convenient. Portable style is shown above.

Write for complete details and prices.

SHAW INSTRUMENT CORP.

P. O. Box L-46 Latrobe, Pennsylvania

CIRCLE 112 ON READER-SERVICE CARD

New...from MARSH!

MARSH Master-mite SOLENOID VALVES

Conduit-type Master-mite. Grommet-type also available.

Small Solenoid Valves that fill a BIG Order

Designed to meet the need for positive-acting tight-seating valves for use on wide variety of media, including oxygen, hydrogen, acetylene, etc.

Two Types:
Conduit type and grommet type. Port sizes 1/8" and 1/4" NPT.

Ten orifice sizes: 3/64" through 1/4".

Wide range of voltages:
Standard with 115 V. A. C. but also available in 12, 24, 208, 230, 460 V. A. C.

Pressure to 540 psi.
Small, but with more strength in the Marsh manner. Coils never overheat. Entire assembly leak tight. Remarkably quiet operation. Cleanable without breaking connections. Used in any position. Bodies either brass bar stock or 18-8 stainless steel. All moving parts stainless. Underwriters' approved for use on oxygen and hydrogen and as safety valves.

Write for new bulletin

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Dept. 42, Skokie, Illinois
Division of Colorado Oil and Gas Corporation
Marsh Instrument & Valve Co., (Canada) Ltd., 8407 103rd St., Edmonton, Alberta, Canada, Houston Branch Plant, 1121 Rothwell St., Sect. 15, Houston, Texas.

CIRCLE 113 ON READER-SERVICE CARD

precision mercurial

BAROMETER — MANOMETERS

Serve or Manually Operated Pressure Controller Available

Measures Absolute or Differential Pressures

Primary Standard Barometers Available

Features Available

Ranges: 0-31", 0-62", or 0-105" inches of mercury.

Temperature and Gravity compensated.

True pressure readings with accuracy guaranteed to .02% of full scale.

Visual sighting or Photo Electric Scanner which indicates pressure changes of less than .0004 inch of mercury.

Stop-bar mechanism for production testing at predetermined points.

Choice of scale graduations: inches, millimeters, millbars, or altitude.

Used by the U. S. Air Force and leading manufacturers where precise instrument calibration is necessary.

31" Type A-1 Barometer

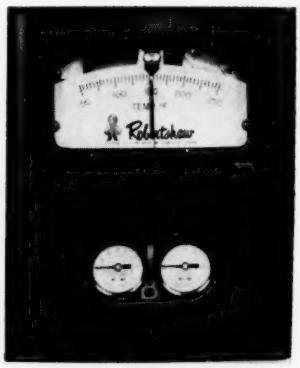
For more information or special problem application call or write:

HASS INSTRUMENT CORPORATION
6173 BRANCH AVENUE • Hickory 9-5454 • Washington 23, D. C.

CIRCLE 114 ON READER-SERVICE CARD

PNEUMATIC CONTROLLER

New indicating Pneumatic Controller for temperature or pressure, offering for the first time a fully-compensated thermal system as a standard feature, designed as a con-

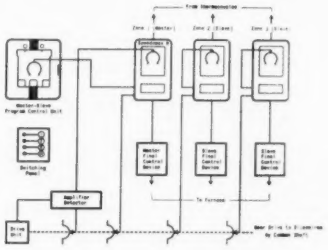


troller, transmitter, or receiver-controller, permits quick adjustment of the control point, proportional band, control action and reset action (the latter available as optional).—*Fulton Sylphon Div., Robertshaw-Fulton Controls Co., Box 400, Knoxville, Tenn.*

CIRCLE 249 ON READER-SERVICE CARD

PROGRAM CONTROL SYSTEM

New Master-Slave Program Control System for fabricating methods where close control over every product phase is required and actual brazing temperatures must be held within ±5° or ±10°F during the brazing cycle, consists of three Speedomax-H



recorder-controllers with appropriate thermocouples and control devices for each of three zones; a Master-Slave Program Control Unit with its associated master drive unit for automatically and continuously adjusting control point setting for each zone; and a switching panel for selecting any one zone as the master. Available with 3-action P.A.T. control for gas-fired furnaces, or with 3-action C.A.T. control for continuous, stepless regulation of input to electric heaters or blankets.—*Leeds & Northrup, 4934 Stenton Ave., Phila. 44, Pa.*

CIRCLE 250 ON READER-SERVICE CARD

HIGH-PRESS BOILER GAGE

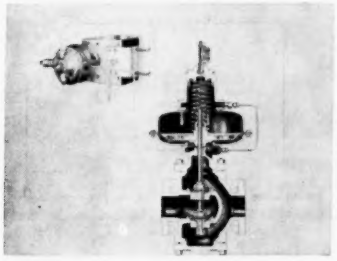
New Refraport Gage, for boiler water pressures for up to 3000 psig, shows water level black, similar to reflex gages, while the steam space

above shows as a line of brilliantly-lighted bullseyes with a clean line of demarcation. A specially designed illuminator at the back of the gage throws a brilliant beam through the ports. Data Unit 358 gives full details.—*Jerguson Gage & Valve C., 80 Adams St., Burlington, Mass.*

CIRCLE 251 ON READER-SERVICE CARD

REMOTE ADJUSTMENT UNIT

New Series 606 Kixcel Remote Control Drive Unit electrically sets pilot-operated gas regulators by turning the pilot's adjusting screw either for an increase or decrease in the reduced pressure of a system. It is

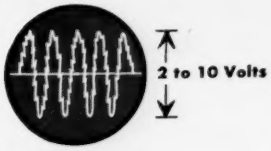


controlled from a remote station by means of conventional telemetering equipment or by a d-c control signal supplied from a polarized signal transmitter. Features include quick and easy manual adjustment, fully adjustable pressure limit switches and various rates of pressure change.—*Fisher Governor Co., Box 307, Marshalltown, Iowa.*

CIRCLE 252 ON READER-SERVICE CARD

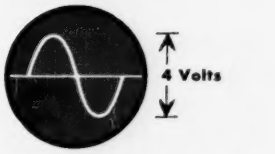
from Honeywell... ANOTHER DIAMOND JUBILEE PRODUCT

WHEN YOU HAVE
extraneous common mode signals



AND WANT TO MEASURE
0.1 to 100 millivolts full scale

AND THEN AMPLIFY



CHOOSE THE NEW HONEYWELL D-C AMPLIFIER

AccuData II

wide-band differential all-transistor D-C Amplifier for strain gages and thermocouples

- **Full Scale Input:** Unbalanced: ±100 μv to ±100 mv Differential: ±3 mv to ±100 mv Open Loop: Below drift level
- **Full Scale Output:** ±2v at 50 ma, dc to 10 kc
- **Frequency Response:** to 20 kc
- **Output Impedance:** Less than 0.5 ohm at dc on all ranges
- **Input Impedance:** Unbalanced 3 to 100 mv ranges; greater than 20 megohms in parallel with 350 micromicrofarads. Differential: Greater than ± 2 megohms
- **Equivalent D-C Input Drift:** Less than 2 μv/10°F ambient temp change on 0.1 to 30 mv input ranges
- **Equivalent Input Noise:** 4μv peak-to-peak on 100 μv to 300 μv range (0-10 cps). 8μv rms on 10 to 30 mv ranges (0 to 100 kc)
- **Common Mode Rejection:** 200,000 at 60 cps on 3 to 30mv ranges

The new Honeywell AccuData II is a completely transistorized D-C Amplifier designed for use in high accuracy data handling systems as a wide-band pre-amplifier for strain gages and thermocouples. Its output can be fed to electronic or electromechanical analog-to-digital converters and simultaneously recorded on galvanometer oscillographs or magnetic tape. Either differential or single-ended input modes can be selected by an eleven position range switch. This switch changes the gain in three-to-one steps. Intermediate gains with high resolution are provided by a ten-turn potentiometer Write for AccuData II Bulletin to Minneapolis-Honeywell, Dept. 50, Boston Division, 40 Life Street, Boston 35, Mass.

Honeywell

First in Control

SINCE 1885

CIRCLE 115 ON READER-SERVICE CARD

HASTINGS
ABSOLUTE PRESSURE INDICATOR
Range: 0.1 - 20 mm Hg
THE VACUUM GAUGE IN THE MILLIMETER Hg RANGE
Practical - Inexpensive - Stable

Hastings Absolute Pressure Indicator is the first of its class—the finest in its field—and the *only* inexpensive electrical gauge now commercially available that covers the hard-to-measure range of 0.1 to 20 millimeters of mercury.

- Direct reading in millimeters of mercury
- Gives continuous reading or recording
- Responds rapidly to temperature changes
- Rugged construction—stable calibration
- Electric signal can be used to operate controllers of standard type
- Inexpensive, easily-cleaned, shock and vibration resistant gauge tubes
- Internal volume of gauge tube less than 1/20 cubic inch
- Ideal in applications where "fail-safe" operation is mandatory

Hastings Absolute Pressure Indicator, Model SP-1. Range: 0.1 to 20mm Hg, Expanded Scale from 0.5 to 5mm Hg

Models covering the 5 to 100 millimeters Hg range available on special order.

COMPLETE LINE OF INDUSTRIAL, COMMERCIAL, AND LABORATORY INSTRUMENTS.
AIR METERS • JET VANES • WIND VELOCITY RECORDERS • AIR DRIFT INDICATORS
VACUUM AND PRESSURE GAUGES

HASTINGS-RAYDIST, INCORPORATED
HAMPTON 67, VIRGINIA

CIRCLE 116 ON READER-SERVICE CARD

GLASS CYLINDERS
RODS • TUBES
CIRCLES & SPECIAL SHAPES

Experimental and Production Blowing
Your Inquiries Invited.

FABRICATED and CUT to Your SPECIFICATIONS

Glass Tubes and Rods for Scientific Use—Lamps, Furniture, Lighting & Decorative Fixtures—Display Domes—Contract Cutters of Tube and Rod.

CRYSTAL GLASS TUBE & CYLINDER CO.
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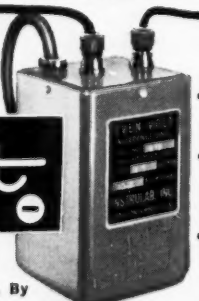
INSTRULAB'S NEW
evenvolt
Constant Voltage Unit

REPLACES BATTERIES IN POTENTIOMETERS
- CONTROLLERS
- INDICATORS
- RECORDERS



Mfg. By
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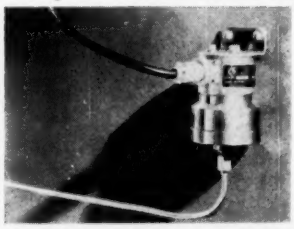
1205 Lamar Street
Dayton 4, Ohio
Phone BA 3-2241

Outstanding FEATURES
- **Eliminates** batteries ...errors due to battery exhaustion
- **Reliable** construction...from quality components, long, trouble-free service
- **A Precise** voltage regulator . . . max. ±.04% for ±20% voltage variation
- **Quickly Installed**... Fits present instrument battery space.
- **No Tubes** to replace

CIRCLE 118 ON READER-SERVICE CARD

PRESSURE TRANSDUCER

New Pressure Transducer, Teledyne Model 227, specially designed to measure corrosive and dynamic fluid or gas pressures up to 50 psig with 1-msec response acts on bonded strain



gages which emit a linear electrical output signal, proportional to the pressure. Infinite resolution, low sensitivity to vibration, high built-in overload protection, and pressure cavity clean-out are its main characteristics.—*Taber Instrument Corp., Electronic Div., Section 243, North Tonawanda, N. Y.*

CIRCLE 253 ON READER-SERVICE CARD

HIGH-PRESS FILTER

New High Pressure Filter for air, water, gas, or oil features operating pressures up to 2,000 psig, a built-in

automatic bypass relief valve, and a quick-change hammer union fitting providing quick filter cartridge change without interrupting flow. Available with up to three filter cartridges of 5, 25, 50 or 75 microns. —*Instruments, Inc., Box 556, Tulsa, Okla.*

CIRCLE 254 ON READER-SERVICE CARD

HIGH TEMP THERMOCOUPLE

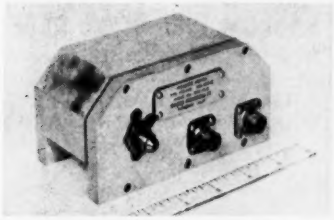
Two new multiple-shielded high-temperature Thermocouple Probes are (1) for gases moving at velocities in excess of 100 ft/sec, with a velocity

recovery factor of approximately 90% and an accuracy of 5° in 1000° (see upper picture) and (2) for low-velocity gas streams where by applying a suction pressure the hot gas is aspirated past the thermocouple at a high velocity,)see lower picture).— *United Sensor & Control Corp., Box 127, Glastenbury, Conn.*

CIRCLE 255 ON READER-SERVICE CARD

PRESSURE SWITCH

New Type P36-1001 Pressure Switch combines a transducer, a solid-state carrier oscillator, ring demodulator, and switching transistor.

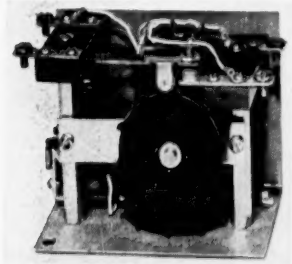


D-c input voltage is converted to ac for excitation of a variable-reluctance magnetic circuit. Range is from 10 to 3000 psig, accuracy: ±1.5% of setting; switch pressure adjustment: ±16% of nominal switch pressure.—*Wiancko Engineering Co., 255 N. Halstead, Pasadena, Calif.*

CIRCLE 256 ON READER-SERVICE CARD

INDUSTRIAL CYCLE TIMER

New Cycle Timer can be used to set up any sequence of on-off combinations within a basic cycle of 150

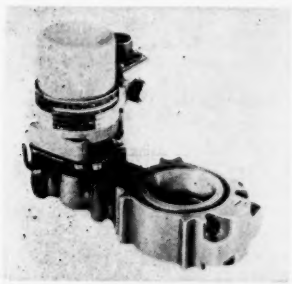


sec. Contact rating is 15 amp at 115 vac. Dual and multi-circuit models also available on the same cycle. Custom timers can be built for any circuit and time requirements.—*Signatrol, Inc., Danville, Ill.*

CIRCLE 257 ON READER-SERVICE CARD

STANDARD GATE VALVES

New and improved family of Gate Valves features mechanically-loaded and retained Teflon seals, advanced



roller type clutches, and complete interchangeability of actuators. Available from stock; mounting is by through-bolts rather than threaded holes.—*Whittaker Controls Div., Telecomputing Corp., 915 North Citrus Ave., Los Angeles 38, Calif.*

CIRCLE 258 ON READER-SERVICE CARD

LOG AUTOMATICALLY

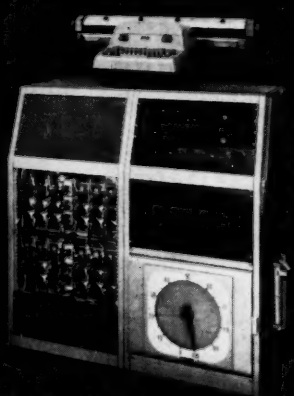
- *for always-current data, gathered from hundreds of points, typewritten or on punched tape*
- *for unfailing accuracy and reliability*
- *for round-the-clock operation*
- *to spot trouble as it develops*
- *to dramatically lower costs*

with a DATA MASTER Automatic Data Logger!

The ONLY automatic Logger in its price range that offers such versatility:

- Logs a variety of INPUTS, such as temperature, humidity, pressure, flow, etc.
- Logs Multiple Ranges, from extreme lows to highs.
- No Obsolescence, off-the-shelf modules can be added to fit changing requirements.
- No maintenance problems, with simple maintenance by your own man—no waiting around for a "factory expert."
- Flexibility thru standard modules for scanning, recording, alarms, etc. You pay for no more than you want, nor settle for less than you need.
- Factory Assembled and tested unit just plugs in—no kit assembly.

Many Data Masters are in use in laboratories, utilities and in industry, performing a wide variety of jobs with accuracy and complete reliability. Users report years of trouble-free operation.



Front panel removed to show Input Modules for logging variety and ranges of data.

PRICES start at $6,800—50 pts.

Find out how a Data Master will solve your problem. Write . . .

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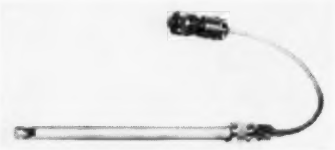
CIRCLE 119 ON READER-SERVICE CARD

HIGH-TEMPERATURE PROBES

New Thermocouple Probes for continuous measurement of furnace and flue gas temperatures can operate to 3100°F and are available with or without water cooling. The uncooled

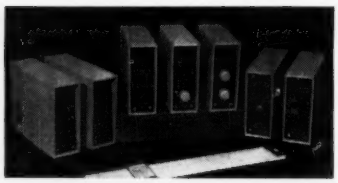


probe, Model T-1006-2, made of molybdenum, has accuracy better than 2% and a time constant faster than 0.8 sec. The cooled probe, Model T-1006-6, designed for the variable immersion applications, can be made in long lengths. Bulletins 8 and 8.3 give details.—*Aero Research Instrument Co., Inc.*, 315 *N. Aberdeen St., Chicago 7, Ill.*

CIRCLE 345 ON READER-SERVICE CARD

DIGITAL TEST EQUIPMENT

New low-cost, Series-3000, coordinated low-speed Digital Test Equipment "building blocks" operate at speeds up to 500 kc as compared with speeds up to 5 Mc in presently available equipment. However, they are directly compatible with the high-speed units, as both employ same logical techniques. Prices on the low-

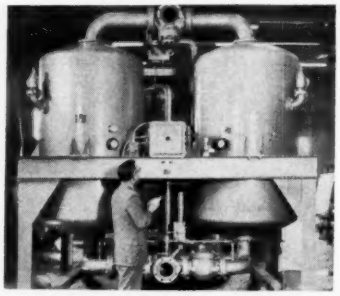


speed units average about half the cost of the comparable high-speed units. Units in the 3000-Series are the Inverter Type 3101, Diode Nor Type 3110, Flip-Flop Type 3201, Delay Type 3301, Clock Type 3401, Pulse Generator Type 3410, and Pulse amplifier Type 3601.—*Digital Equipment Corp., Maynard, Mass.*

CIRCLE 346 ON READER-SERVICE CARD

5000-SCFM DESICCANT DRYER

New Dynamic Desiccant Dryer, Model 4000AB-EESA-8, with capacities up to 5000 scfm measures 11'



high x 11' long x 7-½' deep. It is a heat-reactivated type dryer with an external electric heater and purge blower.—*Trinity Equipment Corp., Cortland, N. Y.*

CIRCLE 347 ON READER-SERVICE CARD

VACUUM IONIZATION GAGE

New long-life Ionization Gage, the BOP (for burn-out proof), Model 527, indicates vacuums from 1 μ to 10^{-7} mm Hg with a sensitivity of

100 mamp/μ which makes it suited for vacuum metallizing, vacuum melting and heat treating, etc. A specially-coated iridium filament that has superior resistance to burn-out at incandescent temperatures is the key to its rugged construction.—*NRC Equipment Corp.*, 160 *Charlemont St., Newton* 61, *Mass.*

CIRCLE 259 ON READER-SERVICE CARD

TEMPERATURE CONTROLLERS

New Tem-Tron Temperature Controllers, utilizing up to five separate temperature control points on a single power supply chassis, feature standard plug-in epoxy potted electronic circuits with sensing elements of the

resistance-wire or thermistor types. On-off controller automatically turns heat on or off to maintain temperature at the desired set-point. At the same time, proportional controller automatically proportions length of time heat is applied to maintain temperature at set point. An anticipating section may be added to either type of controller. Thus control capability of proportional instruments is ±0.25°F, and ±0.5°F for on-off units. —*Electronics Processes Corp. of Calif.*, 436 *Bryant St., San Francisco 7, Calif.*

CIRCLE 260 ON READER-SERVICE CARD

THE FINEST COMPACT **LEADWIRE ADAPTOR** *You Can Buy*
FOR YOUR MgO INSULATED THERMOCOUPLES

Leadwires can now be extended from your MgO insulated thermocouples in a matter of minutes . . . the cold junction can be potted to resist low temperatures or high temperatures . . . will accommodate diameters from .040 to .250 . . . brightly finished to add a professional look to your own thermocouple . . . available from stock for immediate delivery.

Write Today! FOR COMPLETE DETAILS AND PRICES
THERMO-COUPLE PRODUCTS CO. INC.
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CIRCLE 121 ON READER-SERVICE CARD

Vol-O-Flo Linear Gas Flowmeter
For Laboratory Plant Special Equipment

ACCURATE • RUGGED • ADAPTABLE

Meters using laminar flow elements have the highest potential accuracy possible. Accuracy is independent of pipe run. Convenient to use. Available for table, pipe, wall, or flush mounting. Specials to order: Pressure to 2000 psig, temperature to 500° F, overflow checks, H-assemblies. Dial indicator type (Model 30) and element only (Model 10, for customer secondary device) are also available.

Model 20

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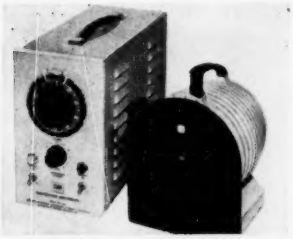
CIRCLE 122 ON READER-SERVICE CARD

RADIANT ENERGY STANDARD

New Model 403 Black Body with Model 100 Temperature Controller represents an accurately adjustable standard of radiant energy for check-



ing and calibrating other infrared sources and measuring instruments. Temperature range is 500°K to 1000°K, with a stability of the radiation-source temperature within ±1°K despite wide changes in ambient temperature, line voltage variations, transients and tube aging.—*Infrared Standards Lab.*, 10555 *Magnolia Ave., Riverside, Calif.*

CIRCLE 261 ON READER-SERVICE CARD

HIGH SPEED COUNTER

New Model 271A is an eight-digit high-speed counter which totalizes impulses up to a maximum of 99,999,999 counts. Maximum impuse rate is 1,200,000 counts/min. The instrument

is completely transistorized and utilizes cold-cathode decade counting tubes, affording low power consumption of less than ten watts, and extreme reliability.—*Oxford Engineering Co.*, 47 *A River St., Wellesley Hills* 81, *Mass.*

CIRCLE 262 ON READER-SERVICE CARD

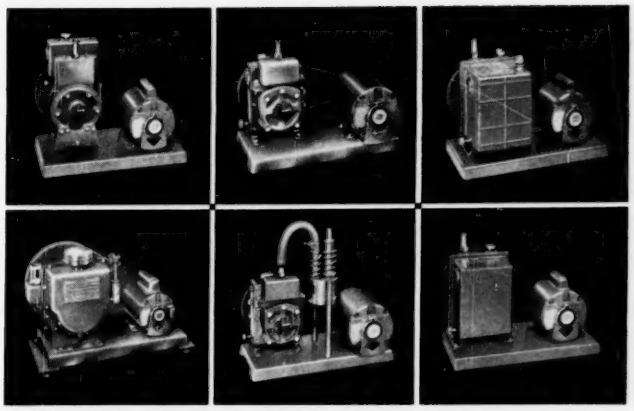
DIGITAL VOLTMETER

New DVM Digital Voltmeter, an all-solid-state, high-speed instrument, is a multi-output data converter con-

sisting of a voltage-to-digital converter and a digital display. It measures bipolar d-c voltages ranging from 1 mv to 1000 v with an accuracy of ±0.1% and a speed of 100 conversions/sec.—*Epsco, Inc.*, 275 *Massachusetts Ave., Cambridge, Mass.*

CIRCLE 263 ON READER-SERVICE CARD

FOR THE BEST IN VACUUM PUMPS SELECT WELCH DUO-SEAL®



They are best because: Every pump is triple tested.
Specified performance guaranteed.
Lowest cost per year of use.
Highest vacuum of any mechanical pump.
Quietest mechanical pump made.

When you buy a Duo-Seal Vacuum Pump, you are buying a pump with a reputation. Over the years Duo-Seal pumps have built up this reputation for long-life dependability, quiet operation, long-term adherence to original specifications.

Rigid design requirements make these pumps quiet operating, long wearing; meticulous factory inspection methods make sure that every pump is perfect when it leaves the plant. Triple testing with McLeod gauges leaves no room for question on final performance.

The superior performance of Duo-Seal Vacuum Pumps is due to the use of Duo-Seal Oil, a specially processed product that maintains these pumps at highest vacuum and efficiency. Chemically stable, with low vapor pressure, Duo-Seal Oil meets the most rigorous laboratory tests. Oil .75 qt.

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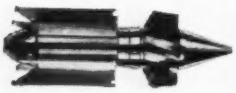
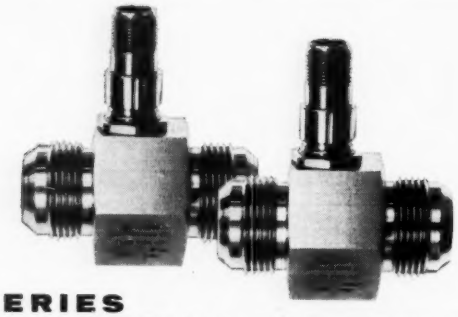
Waugh FLOW SENSORS . . .



a significant advance in flow instrumentation



FF SERIES FLUID BEARING

FB SERIES BALL BEARING

The new Waugh FF and FB Series flow sensors are an outgrowth of more than 25 years experience in the design and production of flow instrumentation. Completely new, yet proven through strenuous testing in actual use, these flow sensors have almost universal application and are the basis for our standard flow instrumentation line.

Both models feature extremely high accuracy, linearity and *infinite* life in use. Decreased bearing drag aids to linearity and practically eliminates maintenance problems.

The turbine rotor of the FF sensor floats entirely on a filtered film of the liquid being measured, obviating wear from either radial or thrust friction. The FB turbine is supported by two ball bearings, which are lubricated and scavenged by the fluid in the line.

FLUIDS — Meters hydraulic oils, cryogenics, corrosive fluids, jet-aircraft fuels, and many other difficult to handle fluids.

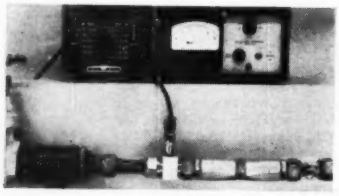
LINEARITY — ±¼%.

REPEATABILITY — The absence of conventional bearing surfaces results in reproducability within 0.1% of flow rate.

EXPECTED LIFE — Infinite.

SIZES and FLOW RANGES — Standard ranges are from 2 to 500 GPM, in sizes from ⅜" to 2¼" line o.d. The FB series is available also in ½" line o.d. model with flow range from 1 GPM. Standard models available in bulkhead length. Other sizes and ranges are available.

LINE PRESSURE — Standard stainless steel unit is suitable for 5000 psi, with higher pressure ratings available.



This FF Series sensor has been operating **continuously** at 35 GPM for **5553** hours to date, and is still functioning perfectly. Expectancy unlimited!

Write for technical bulletin

WAUGH ENGINEERING COMPANY

7842 BURNET AVENUE
VAN NUYS, CALIFORNIA
STate 2-1710

Engineering Representatives in Principal Cities

Waugh

CIRCLE 124 ON READER-SERVICE CARD

AUTOMATIC SCALE

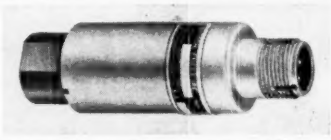
New Model P Automatic Suspension Scale is calibrated with certified test weights to an accuracy of 1/10 of 1% and is officially sealed by the Bureau of Weights and Measures

prior to shipment. Having a 16"-dia dial it is available in the following capacities: 0-250, 0-500, 0-750, 0-1000, 0-2500, 0-5000, 0-7500 and 0-10,000 lb. Principle of operation is based upon compound levers. Mechanism is fully dampened against vibration or flutter.—*W. C. Dillon & Co., Inc., 14620 Keswick St., Van Nuys, Calif.*

CIRCLE 264 ON READER-SERVICE CARD

PRESSURE SWITCH

New 1590-Series Pressure Switch is factory-set to actuate at any desired pressure level within the range

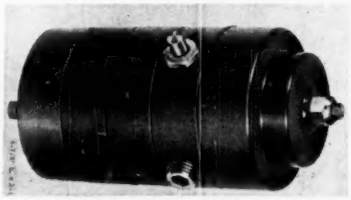


of 0.5 psig and 4,000 psig. All moving parts are environmentally sealed in a rugged aluminum and steel housing. Unit weighs only 2½ oz, is 3" long, and has 0.937" dia.—*Haydon Switch, Inc., Waterbury 20, Conn.*

CIRCLE 265 ON READER-SERVICE CARD

AIR SIGNAL MONITOR

New Mite 74 Monitor with integral 3-way valve for pressure limit protection automatically trips on de-



creasing air signal either to vent or lock up downstream air, without bleeding before or after trip. Trip point is adjustable from 1 to 100 psig, repeatability is ±0.25 psi.—*George W. Dahl Co., Inc., 86 Tupelo St., Bristol, R. I.*

CIRCLE 266 ON READER-SERVICE CARD

NEW FLOOR MODEL A-F

Wilder MICRO-PROJECTOR with VERTICAL LIGHT BEAM

Quality Control plus Cost Control

- Completely versatile. For production inspection or as contour measuring projector.
- Choice of 3 measuring stages 1" x 1", 2" x 2", 2" x 4".
- Full set of lenses between 10x and 100x magnification.
- Full length cabinet eliminates separate worktable.
- Detachable shelf optional.

Write for New 12 page catalog 357.

OPTO-METRIC TOOLS, INC.
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CIRCLE 125 ON READER-SERVICE CARD

FREE ENGINEER'S FACT FILE

A Complete Manual on

MERCURY PLUNGER RELAYS

For all loads up to 60 Amps or 5 H.P.

Single Pole

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FREE: Brand new edition, fully illustrated. Rated as the standard reference manual on all types and applications of Mercury Plunger Relays. 1, 2 and 3 pole hermetically sealed, compact and miniature units that provide millions of continuous makes and breaks without maintenance. No pitting or corrosion.

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CIRCLE 126 ON READER-SERVICE CARD

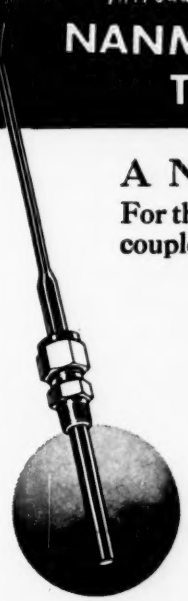
DIFF-PRESS GAGE

New series of Differential Pressure Indicators is electrically operated on 115 v/60 cps ac with a sensing device of a noble metal thermopile installed in a flow tube, which can be installed directly in a line for use as draft gages or for controlling differential pressure in industrial and commercial

heating systems; or they can be installed so as to measure pressure differential across an orifice in an air or gas line, this becoming the equivalent of a remote electrical flowmeter. Being compensated for changes in pressure and temperature of the air or gas, they can be calibrated directly in terms of mass flow if desired. Ranges are from 0-0.01" H_2O (with a sensitivity of 0.0001" H_2O) to 0-0.03", 0.1", 3", 10", 20", 50", and 100" H_2O.—*Hastings-Raydist, Inc., Hampton, Virginia.*

CIRCLE 267 ON READER-SERVICE CARD

Introducing a NEW, FAST-RESPONDING NANMAC "PENCIL PROBE" THERMOCOUPLE



A NEW DESIGN . . .

For the first time - a pencil probe thermocouple with the following features:

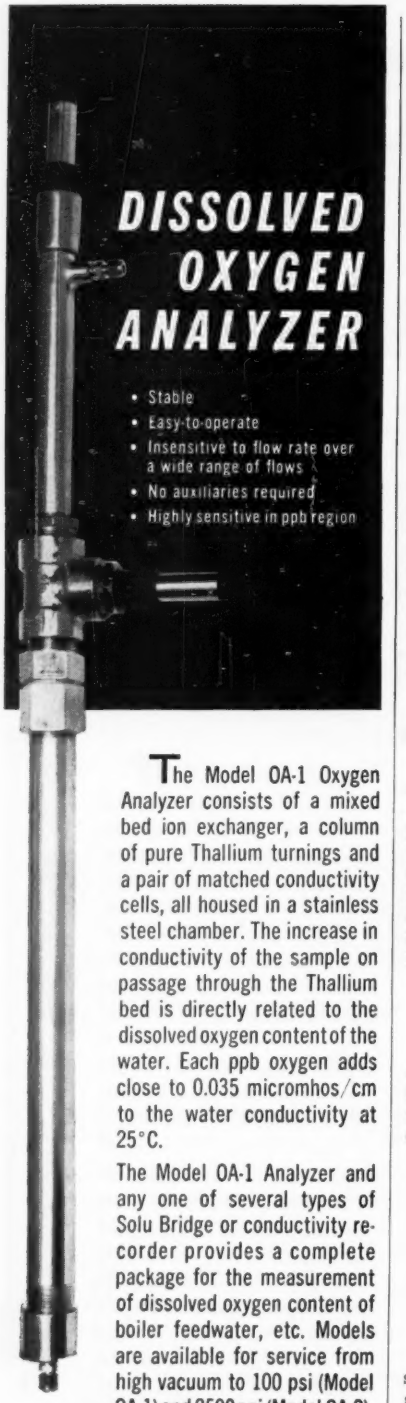
- ✓ *Response time - less than 10 microseconds to transient flow.*
- ✓ *A continuous service temperature of over 2000° F.*
- ✓ *A sensing tip with unlimited life.*

Sensing tip constructed with flat ribbon thermocouple wires of .001 inch thickness and mica insulation of .0002 inch thickness. Thermocouple can be used as a surface, in-wall, or immersion thermocouple. Adjustable gland nut assures pressure seal to 3,000 PSI. All stainless steel construction. Available in all standard thermocouple combinations.

For additional details and models write for Technical Bulletin 250

NANMAC CORPORATION
P.O. BOX 8 INDIAN HEAD, MARYLAND

CIRCLE 127 ON READER-SERVICE CARD



DISSOLVED OXYGEN ANALYZER

- Stable
- Easy-to-operate
- Insensitive to flow rate over a wide range of flows
- No auxiliaries required
- Highly sensitive in ppb region

The Model OA-1 Oxygen Analyzer consists of a mixed bed ion exchanger, a column of pure Thallium turnings and a pair of matched conductivity cells, all housed in a stainless steel chamber. The increase in conductivity of the sample on passage through the Thallium bed is directly related to the dissolved oxygen content of the water. Each ppb oxygen adds close to 0.035 micromhos/cm to the water conductivity at 25°C.

The Model OA-1 Analyzer and any one of several types of Solu Bridge or conductivity recorder provides a complete package for the measurement of dissolved oxygen content of boiler feedwater, etc. Models are available for service from high vacuum to 100 psi (Model OA-1) and 2500 psi (Model OA-2).

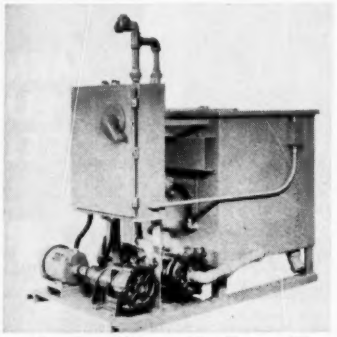
FOR FURTHER INFORMATION WRITE

Industrial Instruments Inc.
89 Commerce Road, Cedar Grove, Essex County, N. J.

CIRCLE 128 ON READER-SERVICE CARD

SOLUTION CONTROLLER

New Automatic Electronic Solution Controller system for concentration of caustic, acidic or aqueous solutions consists of: (1) a concentrate-level-setting controller; (2) a sensing electrode (which measures change in concentration); (3) a magnetic amplifier utilizing output of sensing electrode to control operation of (4) a pump assembly (5) a wash tank; and (6) a combination compound and concentrate holding tank.—*Electro Mechanisms Corp., 7301 Ridgeway Ave., Skokie, Ill.*



CIRCLE 268 ON READER-SERVICE CARD

MINIATURE SELENIUM DIODES

New low-cost subminiature plastic-encapsulated Selenium Diodes capable of operating in ambient temperatures from −50° to +100°C without derating are made in eight types, with peak inverse voltage ranges from 50 to 400 v, at 12.5 ma. Diodes are color-coded for simple identification.—*Radio Receptor Co., 240 Wythe Ave., Brooklyn 11, N. Y.*

CIRCLE 269 ON READER-SERVICE CARD

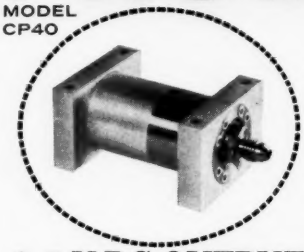
FORMULA CAPSULE

New Formula Capsule which automatically sets correct proportions of feeds, grains, chemicals, flour, etc. consists of a network of miniature electronic components sealed in a shatter-proof protective cover. Integrated with the Richardson "Select-O-Weigh" automatic proportioning panel it is capable of programming the sequence and weighing of up to 24 solid and/or liquid ingredients in a single formula. The pre-set unit is inserted into the receiving slot of the Select-O-Weigh panel and the fully-automatic system can be set into action at the touch of a button.—*Richardson Scale Co., Van Houton Ave., Clifton, N. J.*

CIRCLE 270 ON READER-SERVICE CARD

PACE

MODEL CP40



0-5 V DC OUTPUT PRESSURE TRANSDUCER

Ranges: 5 to 1,500 psi — Gage, Differential or Absolute—Accepts corrosive fluids, both sides.

Insensitive to Shock and Vibration.

Input: 25-30 Volts DC at 20 ma.

Combines Variable Reluctance Pressure Transducer and Carrier Demodulator for voltage controlled telemetering and other DC systems.

PACE engineering company
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North Hollywood, California
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CIRCLE 129 ON READER-SERVICE CARD

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T LAMINATED & SOLID GLASS **FILTERS** INDUSTRIAL • SCIENTIFIC • PHOTOGRAPHIC

I PRECISION OPTICS WINDOWS • PRISMS • WEDGES

F SPECIALIZED GLASS VYCOR • PYREX • QUARTZ

F PRECISION HOLE DRILLING TOLERANCES TO .0001"

E PRECISION EDGING SAWING, MACHINING ON ALL TYPES OF GLASS & CERAMICS

N PRECISION OPTICAL MACHINING METAL LENS MOUNTS • BARRELS • EYEPIECES

AUTOMATIC SCREW MACHINES TO 4" DIA. — ALSO HAND SCREW MACHINES — ENGLISH & METRIC THREADS OUR SPECIALTY.

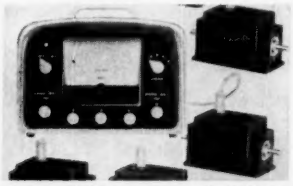
Write for Filter Transmission Curve Catalog.

Tiffen QUALITY PRODUCTS
TIFFEN OPTICAL CO.
INDUSTRIAL DIVISION
71 Jane St., Roslyn Heights, L.I., N.Y.

CIRCLE 130 ON READER-SERVICE CARD

TORQUEMETER

New Torquemeters use up to five pickup heads to measure torques of rotating shafts. Available with ranges from 0.1 in-oz to 500 in-oz they are

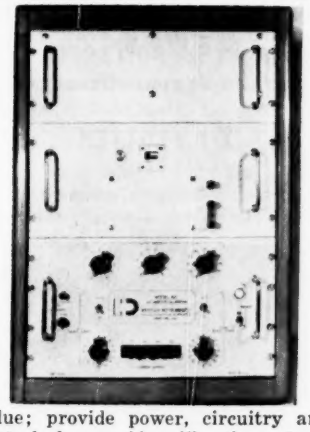


accurate within ±2% of full scale. Torque readings are independent of shaft speeds between 50 rpm and 24,000 rpm, and of the direction of shaft rotation.—*Metron Instrument Co., 432 Lincoln St., Denver 3, Colo.*

CIRCLE 271 ON READER-SERVICE CARD

CALIBRATION CONSOLES

Four new Model 60 Consoles furnish a-c and d-c instrument calibration accuracy of 0.05% of indicated



value; provide power, circuitry and control for rapid calibration of all types of portable, panel, switchboard, and recording-type instruments.—*Weston Instruments Div., Daystrom, Inc., 614 Frelinghuysen Ave., Newark, N. J.*

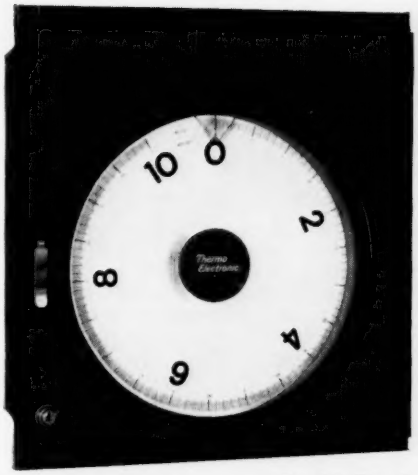
CIRCLE 272 ON READER-SERVICE CARD

RADIATION THERMOMETER

New Thermodot Radiation Thermometer, Model TD-3, measures and controls temperature of moving or stationary objects without physical

contact. Using infrared detection it gives rapid and accurate response automatically and continuously for industrial in-plant use. Unit consists of (l to r) rack-mounted indicating controller and independent power supply, and hermetically sealed optical head.—*Radiation Electronics Co., a div. of Comptometer Corp., 5600 W. Jarvis St., Chicago 48, Ill.*

CIRCLE 273 ON READER-SERVICE CARD



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Self Balancing Indicator

These new potentiometer and bridge type indicators give you full 34″ scale readability at a distance. Within seconds, you can check accurately any one of several hundred sensing elements connected through multi-point switching systems. The instrument will automatically indicate any variable, convertible to DC potential, current, or resistance.

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The potentiometer indicator is standardized semi-automatically using full amplifier sensitivity. Full scale balancing speed—5 seconds. Range changes are easily made in the field. Instrument accuracy is ±0.25% of full scale—sensitivity is ±0.125%.

No matter what your measuring needs, you can best meet them with Thermo Electronic Instruments.

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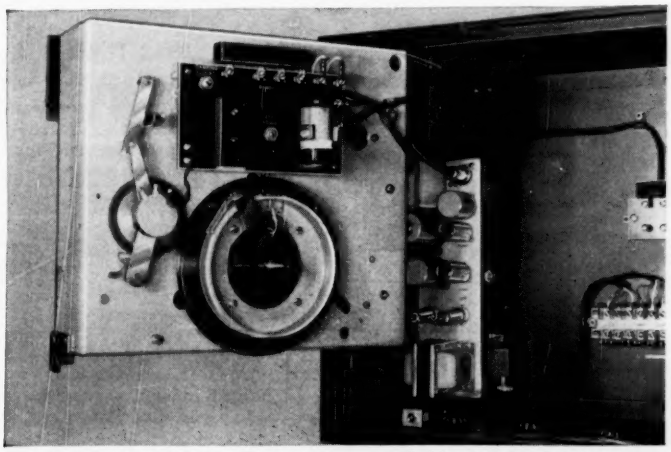

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Thermo Electric CO., INC. SADDLE BROOK, NEW JERSEY
In Canada: THERMO ELECTRIC (Canada) LTD., Brampton, Ontario

CIRCLE 131 ON READER-SERVICE CARD

MINIATURE MANIFOLDS

for

Multi-Purpose CONTROL

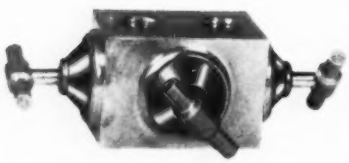


Photo ½ actual size

PACKLESS

"DEMI" M2 SERIES

All models of the standard Dahl "Demi" M2 series of three-valve manifolds are readily adaptable to clean liquid, gas and vapor applications. The size of these manifolds makes them especially suitable for pilot plant, aircraft and marine applications, flow control and automation. They are miniature in size, yet their patented form for bubble-tight shutoff makes them comparable to much larger valves in performance.

These manifolds consist of two block valves and one bypass valve in place of 3 separate valves . . . they eliminate two tees, four nipples and eight threaded connections. Models of the "Demi" M2 series come in a variety of barstock materials and may be ordered with special features such as: bolted bonnets, swaged-in TEFLON seats, toggle actuators, etc.

PRESSURE RATING Metal Body & Diaphragm Neoprene Diaphragm	 750 psi at 450°F 100 psi at 180°F
MAXIMUM Cv	0.4
CONNECTIONS	1/16", 1/8", 1/4" N.P.T.

Send for the "DEMI" Catalog D-1 and other technical data on Dahl pneumatic and hydraulic valves.

GEORGE W. DAHL COMPANY, INC.

86 TUPELO STREET, BRISTOL, RHODE ISLAND

CIRCLE 132 ON READER-SERVICE CARD

TEMPERATURE TRANSDUCERS

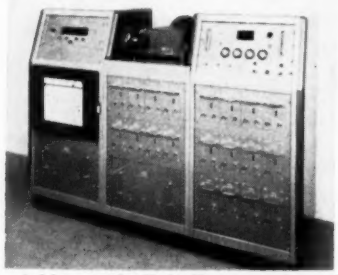
New line of modularized Temperature Transducers features tubes that are variable in length for either gas- or fluid-immersion applications. Out-

puts are from 0 to 5 v; ranges are from −320° to +1000°F. Sensing elements are available in three different materials: nickel-iron, platinum, and thermistor (semiconductor oxides).—*Arnoux Corp., 11924 W. Washington Blvd., Los Angeles 66, Calif.*

CIRCLE 274 ON READER-SERVICE CARD

DIGITAL RECORDING SYSTEM

New Digital Recording System for automatic testing of vacuum tubes will sequentially select up to 200 input

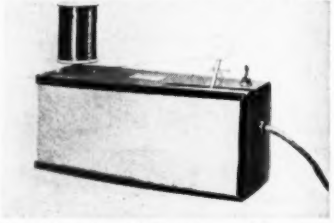


variables and digitally record each variable with 3-digit point identification via a motorized tape punch. Data are recorded in an 8-channel code suitable for use with an IBM 046 or 047 Tape-to-Card Converter. System accuracy is ±0.5% of full scale. Bulletin 350-8 gives details.—*Datex Corp., 1307 So. Myrtle Ave., Monrovia, Calif.*

CIRCLE 275 ON READER-SERVICE CARD

AUTOMATIC TENSION CONTROL

New Auto-Tension Control, Catalog No. 510-A-116, a precisely regulated unit to spool and unspool fine-gage material, provides constant predeter-

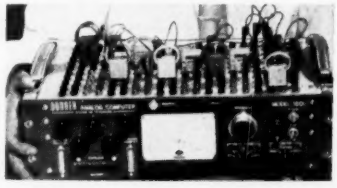


mined tension through a wide range of speeds. Unit consists of four major components: an a-c motor, a control unit, a sensing device, and an automatic brake. Controllable tension range extends from 1.5 to 140.0 grams with winding speeds from 0 to 1000 ft/min.—*Diehl Mfg. Co., Somerville, N. J.*

CIRCLE 276 ON READER-SERVICE CARD

23-POUND ANALOG COMPUTER

New Model 3500 Computer designed for educators and scientists, claimed to be the smallest full-fledged analog computer ever made, a 10-amplifier model weighing just 23 lb, solves up

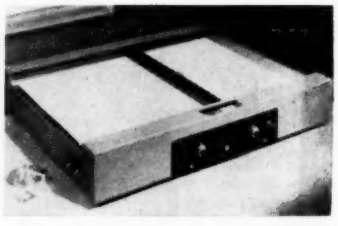


to a seventh-order differential equation or a ninth-degree Laplace transform and performs accurately with 1% or 0.1% computing components. For solving more complex problems, up to three Model 3500 computers can be slaved together for 10-, 20-, or 30-amplifier operation. Specs include: total d-c gain—15 x 10^6; output—±100 v @4 ma; output impedance—less than 1 ohm; noise level—less than 2 mv rms; drift—less than 100 μv.—*Donner Scientific Co., Concord, Calif.*

CIRCLE 277 ON READER-SERVICE CARD

X-Y PLOTTER

New HR-94 X-Y Recorder multiplies small mechanical movements up to 1000:1. Twenty-μin movements are



readily detectable. Uses standard 24 x 36" D-size or 24" rollstock graph paper.—*Houston Instrument Corp., 1717 Clay Ave., Houston 3, Tex.*

CIRCLE 278 ON READER-SERVICE CARD

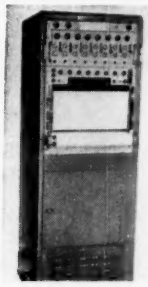
CIRCUIT SCANNER

New Circuit Scanner device, utilizing a single pair of wires for telemetering indication and control systems, is a synchronous commutator using hermetically-sealed magnetic switches instead of sliding contacts. Switches are operated in sequence by a permanent magnet mounted on a rotating arm which is driven by a rugged clock motor. Signals are trasmitted through relays which maintain the circuit for the time required to transmit a signal and, if desired, to receive a return signal from the other end of the line. Scanners operate continuously, hence no extra starting circuits are required. Bulletin 5905 contains details.—*Femco, Inc., Irwin, Penna.*

CIRCLE 279 ON READER-SERVICE CARD

OSCILLOGRAPHIC RECORDER

New 8-channel direct-writing Oscillographic Recording System, 958-1500, accepts up to eight floating or grounded inputs and has a maximum



sensitivity of 10 μv per chart division. Plug-in printed circuitry is transistorized and includes up to eight channels of amplification, common power supply, and built-in MOPA mounted behind a single 7"-high panel.—*Sanborn Co., Industrial Div., 175 Wyman St., Waltham 54, Mass.*

CIRCLE 280 ON READER-SERVICE CARD

VIBRATION METER

New Model T-1A Vibration Meter, which is a completely portable, battery-powered, transistorized unit furnishing direct readings of the velocity, displacement amplitude, and acceleration components of vibration, and (from a simple computation) its frequency, has range and accuracy previously associated only with laboratory-type instruments. Accepting six simultaneous transducer outputs, it provides readings of up to 1000 g acceleration, 0.01—100 in/sec velocity and 0.001—10 in displacement at better than 5% overall accuracy.—*Southwestern Industrial Electronics Co., a Div. of Dresser Industries, Inc., 10201 Westheimer Rd., Box 13058, Houston 19, Tex.*

CIRCLE 281 ON READER-SERVICE CARD

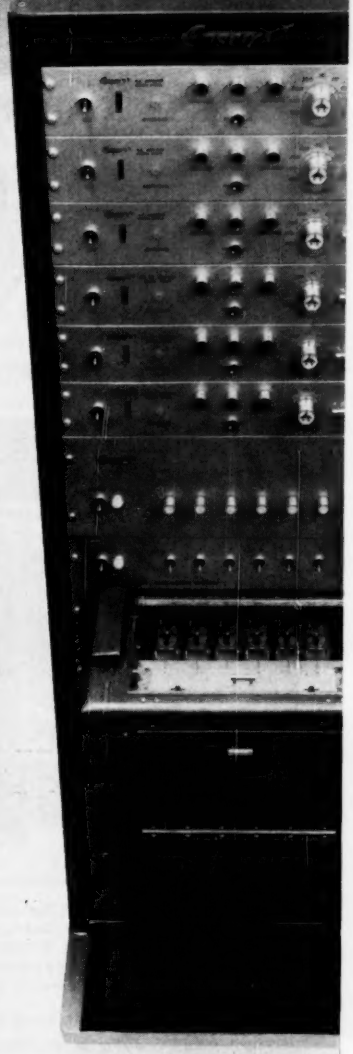
DIRECT-RECORDING OSCILLOGRAPH

New Model 1108 Visicorder for high-speed recording of up to 24 channels of high-frequency, high-

sensitivity information from dc to 5000 cps has chart speeds adjustable in 15 variations from 0.05 to 80"/sec which are pushbutton-selected.—*Minneapolis-Honeywell, Heiland Div., 5200 East Evans Ave., Denver 22, Colo.*

CIRCLE 282 ON READER-SERVICE CARD

VIEWED FROM ANY ANGLE



EPSCO WORCESTER RECORDERS LEAD THE FIELD

In production testing, research and development engineering for all industry where Versatility, Performance and Economy are essential.

Take a look at these important Angles.

VERSATILITY

Interchangeable amplifiers will accommodate a wide range of transducers. Whatever the level or character of the signal, there is an EPSCO preamplifier to handle it.

PERFORMANCE

Sensitivity — from 10uv per mm and Strain measurement as low as 1 micro-inch per inch per mm.
Frequency Response — from D.C. to 200 cps produced through Plug-in compensators which provide extended frequency response or sharp cut-off.
Chart Speed — from .05mm to 500mm per sec.

ECONOMY

- Low initial cost.
  Model 8205-6 (illustrated) 6 channel ink writing system complete $4,365.00
- Low operating cost.
  Compared to other writing systems, EPSCO's operating costs average up to 5 times less.

NO ADDITIONAL EQUIPMENT OR ACCESSORIES ARE NEEDED TO MAKE THIS DYNAMIC RECORDING SYSTEM COMPLETE.

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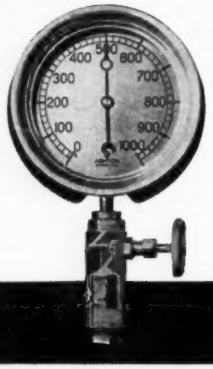
CAMPBELL MICRO BEAN

UNIVERSAL PULSATION DAMPENER

A Campbell Micro-Bean cures a headache ten times as fast as aspirin provided the headache is caused by a pressure gauge with a bad case of the jitters. Rapidly becoming the standard pulsation dampener in many industries all over the world.



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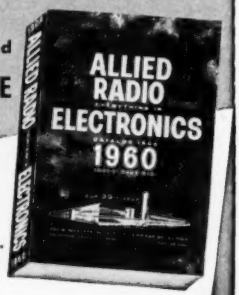

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ICS NEW PLANTS AND MERGERS

GENERAL PRECISION EQUIPMENT CORP. announces that its four principal subsidiaries GPL (General Precision Lab), KEARFOTT, LIBRASCOPE, and LINK AVIATION have become divisions of GENERAL PRECISION, INC., a new operating company.

BENSON-LEHNER CORP. announces the merger of DOCUMENTATION, INC. with the corporation.

SWARTWOUT CO. has come to an agreement with the *Crane Company* by which it will be acquired by Crane and operated as a division.

MINNEAPOLIS-HONEYWELL's Davies Labs Div. has been renamed the Industrial Systems Division.

SHAW INSTRUMENT CORP. has acquired by merger CERAMIC-METAL ASSEMBLIES CORP. of Latrobe, Penna.

ICS PEOPLE IN THE NEWS

DAYSTROM, INC. announces election of *Charles D. Manhart* as vice president.

VEEDER-ROOT has appointed *Arthur E. Kallinich*, vice president in charge of new products and new business,

PORTABLE MILLIVOLT POTENTIOMETER
WITH
LABORATORY ACCURACY

MODEL E-3067 POTENTIOMETER

- 2 RANGES, 0-16.1 & 0-80.5
- MANUAL COMPENSATOR WILL OPERATE ABOVE & BELOW REF. JUNCTION TEMPERATURE
- SPOT-LIGHT GALVANOMETER
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CIRCLE 136 ON READER-SERVICE CARD

F. L. KATZMANN
DuMont

N. A. MARSHALL
Leach

R. P. BROWN
M-H

Charles Lombardi sales manager of the counting division, *George Logan* manager of market research and advertising, and *Bob Perfect* catalog sales supervisor.

DuMONT LABS announce promotion of *Fred L. Katzmann* to manager of circuit design for the instrument engineering department.

LEACH CORP. has appointed *Neil A. Marshall* chief engineer of its Special Products Div.

MINNEAPOLIS-HONEYWELL's *Dr. Richard P. Brown,* former president of Brown Instrument Co., now a Honeywell director, recently was honored by Drexel Institute of Technology when his portrait was unveiled in the new library center.

KULITE SEMICONDUCTOR PRODUCTS has appointed *Anthony D. Kurtz* general manager and executive vice president.

ULTRASONIC INDUSTRIES, INC. is a new organization formed by *Paul Martin Platzman,* pioneer in the ultrasonic industry.

THERMOCOUPLES
THAT WILL WITHSTAND 3000°F AND UP TO 50,000 PSI

LONG LIFE
Sheath Diameters, .04 to .32
Thermocouple Lengths to 50 feet
Complete Thermocouples made to every requirement.

NEW, SIMPLE CONSTRUCTION

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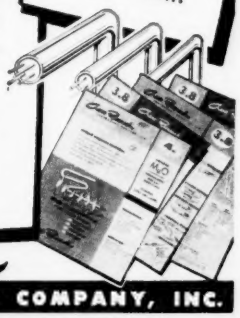

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Surface
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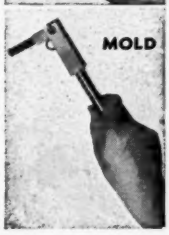

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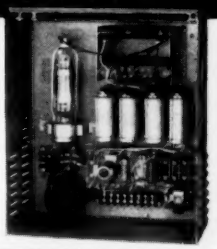
CIRCLE 138 ON READER-SERVICE CARD

Electronically stops, starts, reverses! Controls variable motor speeds!

***New!* HELLER C-60 ELECTRONIC CONTROLLER**
with Separate Control Station Component and Matching ¾ h. p. Motor



Controller, in steel cabinet 14" wide x 16" high x 6" deep, is hot when outside switch is on. It operates a ¾ h.p. shunt wound motor on 220-230 volts, 50-60 cycles single phase.

Control Station Component has three simple controls for coarse or fine settings. Housed in a 2" x 2" x 9" steel box, the control station is connected to controller with a 10-foot 10-conductor vinyl jacketed cable.

Motor is ¾ h.p. at 2400 rpm with full torque from 300 rpm, ball bearing shunt wound with interpole, on frame J66-type DM by Master Electric Co. A 7-foot 4-conductor vinyl jacketed cable comes with motor. Motor and controller are operated from the control station.

C-60 CONTROLLER and CONTROL STATION
f.o.b. Las Vegas, Nev. **$240**
¾ H. P. MOTOR
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Longer motor and controller cables supplied on order.

HELLER COP ELECTRONIC COMPONENTS
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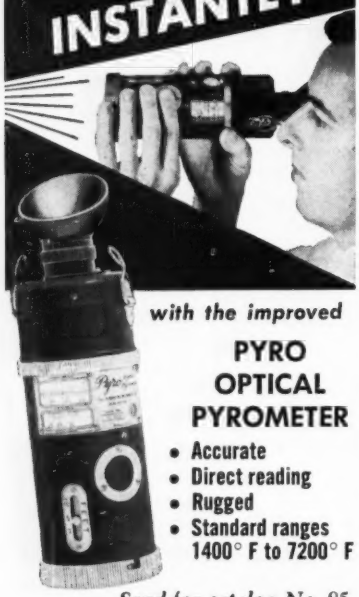
INSTANTLY



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- Standard ranges 1400° F to 7200° F

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CIRCLE 141 ON READER-SERVICE CARD

NEW LITERATURE

VALVES

INDUSTRIAL CONTROLS. 92-page general catalog illustrates and describes automatic valves, instruments, and accessories with application data and specifications.—General Controls Co., 801 Allen Ave., Glendale 1, Calif.

CIRCLE 283 ON READER-SERVICE CARD

BUTTERFLY VALVES. 4-page Bulletin 50-1 describes the complete line of Continental butterfly valves.—Continental Equipment Co., Div. of Fisher Governor Co., Coraopolis, Penna.

CIRCLE 284 ON READER-SERVICE CARD

WATER CONTROL VALVES. 8-page Bulletin G-5A shows water control installations using surge-relief-, altitude-, check-, and pressure-reducing valves.—Golden Anderson Valve Specialty Co., 1232 Ridge Ave., Pittsburgh 33, Pa.

CIRCLE 285 ON READER-SERVICE CARD

AIR VALVES. 12-page Bulletin 234-A titled "Valve Finder" contains descriptions and C_v data of 2-way, 3-way, 4-way, and speed-control valves actuated by solenoid, pressure, cam, hand, or foot.—Hannifin Co., a Div. of Parker-Hannifin Corp., 501 South Wolf Rd., Des Plaines, Ill.

CIRCLE 286 ON READER-SERVICE CARD

VALVES. 4-page Form 6S-2278 contains illustrations and technical data on check, relief, shutoff, plug, and custom-made valves.—Circle Seal Products Co., Inc., 2181 East Foothill Blvd., Pasadena, Calif.

CIRCLE 287 ON READER-SERVICE CARD

REGULATORS AND RELIEF VALVES 4-page bulletin describes Atlas No. 171 Type D valves which can be used as pressure reducing or relief valves, or pump governors.—Atlas Valve Co., 280 South St., Newark 5, N. J.

CIRCLE 288 ON READER-SERVICE CARD

PNEUMATIC CONTROLS. 4-page Folder PC 1.20 illustrates and describes motor-, solenoid-, pressure-, and manually-actuated control elements such as shutoff valves, selector valves, pressure regulators, relief and check-valves, and ram air scoops.—Whittaker Controls, Div. of Telecomputing Corp., 915 North Citrus Ave., Los Angeles 38, Calif.

CIRCLE 289 ON READER-SERVICE CARD

PRESSURE, WEIGHT

BOILER WATER GAGES. 2-page Data Unit 360 gives features and technical data on Refracolor gages.—Jerguson Gage & Valve Co., 80 Adams St., Burlington, Mass.

CIRCLE 290 ON READER-SERVICE CARD

BELT WEIGHER. 2-page Bulletin 36.20-1 describes and illustrates a pneumatically-operated belt (stream) weigher for continuous weighing of dry materials.—Omega Division of B-I-F Industries, Inc., Providence 1, R. I.

CIRCLE 291 ON READER-SERVICE CARD

FORMULA CAPSULE. 2-page Data Sheet 5904 describes the portable capsule formulator which programs the weighing of up to 24 solid and/or liquid ingredients.—Richardson Scale Co., Van Houten Ave., Clifton, N. J.

CIRCLE 292 ON READER-SERVICE CARD

PRESSURE GENERATOR. 4-page Catalog 859 features accessories and tools for use with valves and fittings required by high pressure systems.—High Pressure Equipment Co., Inc., Erie, Penna.

CIRCLE 293 ON READER-SERVICE CARD

SUSPENSION SCALE. 8-page Bulletin 58E describes and illustrates Model P Suspension Scale with applications.—W. C. Dillon & Co., Inc., Box 3008, 14620 Keswick St., Van Nuys, Calif.

CIRCLE 294 ON READER-SERVICE CARD

TEMPERATURE

THERMOWELLS. 4-page bulletin contains descriptions and dimensional sketches of test wells.—Trinity Equipment Corp., Cortland, N. Y.

CIRCLE 295 ON READER-SERVICE CARD

THERMAL SYSTEMS. 4-page Specification S690-3 describes all wet-and-dry-bulb thermal system components—bulbs, tubing and accessories—which are used with brown filled-system thermometer-psychrometers.—Minneapolis-Honeywell Regulator Co., Industrial Div., Wayne and Windrim Aves., Phia. 44, Pa.

CIRCLE 296 ON READER-SERVICE CARD

TEMPERATURE MONITOR. 2-page bulletin describes the Model 310 Omniguard which uses Edison resistance temperature detectors to measure and monitor remotely located temperatures.—Thomas A. Edison Industries, McGraw-Edison Co., Instrument Div., West Orange, N. J.

CIRCLE 297 ON READER-SERVICE CARD

PYROMETER INDICATORS. Two two-page Bulletins, 0031 and 0032, cover operating features, applications, standard ranges, and standard specifications of Types Z21 and Z23 pyrometer indicators.—Atlantic Pyrometers, Inc., 190 Warburton Ave., Hawthorne, N. J.

CIRCLE 298 ON READER-SERVICE CARD

TERMINAL BOXES. 4-page Bulletin 28 describes line of weatherproof multi-junction thermocouple terminal boxes.—Thermo Electric Co., Inc., Saddle Brook, N. J.

CIRCLE 299 ON READER-SERVICE CARD

PUMPS, LEVEL

METERING PUMPS. 12-page Catalog File 420.200 describes a new metering pump line, the Series 200.—Wallace & Tiernan Inc., 25 Main St., Belleville 9, N. J.

CIRCLE 300 ON READER-SERVICE CARD

LEVEL TRANSMITTERS. 4-page Product Specification P31-1 covers pneumatic force-balance transmitters for measurement of level over range spans of 1" to 2000" H_2O.—Bailey Meter Co., 1050 Ivanhoe Rd., Cleveland 10, Ohio.

CIRCLE 301 ON READER-SERVICE CARD

CHEMICALS METERING PUMPS 4-page Bulletin 530 describes line of Pulsafeeder automatic chemicals me-

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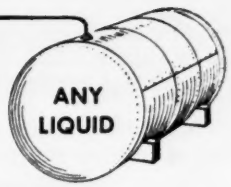

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CIRCLE 143 ON READER-SERVICE CARD

tering pumps for handling corrosive and non-corrosive chemicals.—Lapp Insulator Co., Process Equipment Div., 111 Hall St., LeRoy, N. Y.

CIRCLE 302 ON READER-SERVICE CARD

POSITIVE DISPLACEMENT METERING. 6-page brochure, Form 102, explains operation of the air-powered 1600 Series automatic metering, mixing, and dispensing equipment for viscous compounds.—Pyles Industries, Inc., 20855 Telegraph Rd., Detroit 41, Mich.

CIRCLE 303 ON READER-SERVICE CARD

METERING PUMP. 4-page Bulletin P-21 describes operating principles of the Servo-Gauge metering pump and its controller.—Associated Control Equipment, Inc., Box 136, Coraopolis, Penna.

CIRCLE 304 ON READER-SERVICE CARD

TIME, COUNT

REVOLUTION COUNTERS. 8-page pocket-size Folder entitled, "A Fresh Edge on Competition," lists advantages of including counters in the design of machinery.—Veeder-Root, Inc., Hartford 2, Conn.

CIRCLE 305 ON READER-SERVICE CARD

RECORDER TIMERS. 5-page bulletin describes and illustrates line of recorder timers.—Lux Clock Mfg. Co., Inc., Waterbury 20, Conn.

CIRCLE 306 ON READER-SERVICE CARD

INFRARED ANALYZER. 4-page Bulletin No. 0705-3 contains complete details on the new M-S-A Model 300 LIRA infrared analyzer.—Mine Safety Appliances Co., 201 North Braddock Ave., Pittsburgh 8, Pa.

CIRCLE 307 ON READER-SERVICE CARD

OXYGEN ANALYZER. 2-page Bulletin C-959 contains features, specs, and accessories of dissolved oxygen analyzer.—Industrial Instruments Inc., 89 Commerce Rd., Cedar Grove, N. J.

CIRCLE 308 ON READER-SERVICE CARD

AUTOMATIC ANALYSIS. 2-page bulletin describes three out of over a thousand systems using the AutoAnalyzer. Technicon Controls, Inc., Research Park, Chauncey, N. Y.

CIRCLE 309 ON READER-SERVICE CARD

GAS CHROMATOGRAPH. 4-page Product Data File LOE-3 describes features and operation of Model 15 Gas Chromatograph.—Loe Engineering Co., 237 North Fair Oaks, Pasadena, Calif.

CIRCLE 310 ON READER-SERVICE CARD

DIGITAL INSTRUMENTATION

DIGITAL PLOTTER. 4-page brochure describes and illustrates Model 201 high-speed digital plotter.—Tally Register Corp., 5300—14th Ave., N. W., Seattle 7, Wash.

CIRCLE 311 ON READER-SERVICE CARD

DIGITAL INSTRUMENTATION. 12-page catalog illustrates and specifies counter-timers, frequency meters, readouts, printers, time code generators, etc.—Computer Measurements Co., 12970 Bradley Ave., Sylmar, Calif.

CIRCLE 312 ON READER-SERVICE CARD

BALL/DISC INTEGRATOR. 4-page Catalog 10M-2 contains description, illustrations, and applications of improved ball/disc integrator.—Librascope, Inc., 40 E. Verdugo Ave., Burbank, Calif.

CIRCLE 313 ON READER-SERVICE CARD

MAGNETIC TAPE RECORDER. 20-page Brochure 2025 covers the FR-100B recorder/reproducer.—Ampex Data Products Co., 934 Charter St., Redwood City, Calif.

CIRCLE 314 ON READER-SERVICE CARD

COMPUTER COMPONENTS. 4-page issue No. 2 of "3C Pulse" contains illustrations, specs, and schematic diagrams of 7 packaged logical elements.—Computer Control Co., Inc., Eastern Div., 983 Concord St., Framingham, Mass.

CIRCLE 315 ON READER-SERVICE CARD

DIGITAL CONTROL COMPUTER. 12-page Bulletin GEA-6884A contains complete information on Model 312 computer for process or control computing systems.—General Electric Co., Computer Dept., Phoenix, Ariz.

CIRCLE 316 ON READER-SERVICE CARD

TAPE RECORDER. 12-page Bulletin 1576 describes Type 5-752 Magnetic Tape Recorder/Reproducer.—Consolidated Electrodynamics Corp., 360 Sierra Madre Villa, Pasadena, Calif.

CIRCLE 317 ON READER-SERVICE CARD

DIGITAL COMPONENTS. Folder contains two 2-page bulletins illustrating and specifying logic blocks and modules.—Control Equipment Corp., 19 Kearney Rd., Needham Heights 94, Mass.

CIRCLE 318 ON READER-SERVICE CARD

ELECTRONIC CHRONOGRAPH. 2-page Technical Bulletin 104A contains operational characteristics and technical specs of the Millimicrosecond Quantizer.—Computer Equipment Corp., 1931 Pontius Ave., Los Angeles 25, Calif.

CIRCLE 319 ON READER-SERVICE CARD

ANALOG COMPUTER. 2-page Brochure "Analog Computer CM-2" describes and illustrates solid-state computing device for mathematical calculations.—Southwestern Industrial Electronics Co., a div. of Dresser Industries, 10201 Westheimer Rd., Box 22187, Houston 27, Tex.

CIRCLE 320 ON READER-SERVICE CARD

SCALER-ANALYZER. 4-page bulletin illustrates and describes the RCLiac 128 which features number and curve display.—Radiation Counter Labs., Inc., Nucleonic Park, 5121 W. Grove St., Skokie, Ill.

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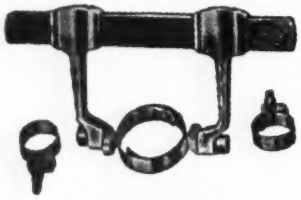

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DIGITAL TAPE HANDLER. 8-page brochure on the FR-400 digital magnetic tape handler includes complete specs.—Ampex Instrumentation Advertising, 934 Charter St., Redwood City, Calif.

CIRCLE 322 ON READER-SERVICE CARD

DIGITAL INSTRUMENTATION. Folder titled Digital Instrumentation contains 25 two- and four-page bulletins on digital systems, instruments, and components.—Datex Corp., 1307 S. Myrtle Ave., Monrovia, Calif.

CIRCLE 323 ON READER-SERVICE CARD

X-Y PLOTTER. 6-page bulletin illustrates and describes Model 210 including operating information.—Librascope, Inc., 808 Western Ave., Glendale, Calif.

CIRCLE 324 ON READER-SERVICE CARD

CONDUCTIVITY, DENSITY

pH AND REDOX. 2-page Data Sheet ND46-96(100) describes Speedomax H indicators, recorders and controllers for pH and redox.—Leeds & Northrup Co., 4934 Stenton Ave., Phila. 44, Pa.

CIRCLE 325 ON READER-SERVICE CARD

CONDUCTIVITY CONTROLLER. 4-page bulletin describes electronic conductivity controller for metal washing operations.—Electro Mechanisms Corp., 7301 Ridgeway Ave., Skokie, Ill.

CIRCLE 326 ON READER-SERVICE CARD

SLURRY DENSITY CONTROL. 2-page Bulletin ASR-3 gives specs and performance data of density measurement and control gage for use on pipes up to three inches in dia.—Ohmart Corp., 2236 Bogen St., Cincinnati 22, Ohio.

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ELECTRICAL, ELECTRONIC INSTRUMENTS

RECORDING MICROAMMETER. 2-page Form 1159 describes and specifies portable recording d-c microammeter. Esterline-Angus Co., Box 596, Indianapolis 6, Ind.

CIRCLE 328 ON READER-SERVICE CARD

AUTOMATIC SPECTROMETER. 4-page Form 3029-9 describes the Model ASP-1ADR Print-and-Plot Spectrometer.—Victoreen Instrument Co., 5806 Hough Ave., Cleveland 3, Ohio.

CIRCLE 329 ON READER-SERVICE CARD

ELECTRONIC SENSING CONTROL. 2-page Bulletin 400 describes security electronic sensing control for detecting, counting, measuring and recognizing objects as they enter a capacity field.—Security Controls, Inc., 503 Franklin St., Buffalo 2, N. Y.

CIRCLE 330 ON READER-SERVICE CARD

IMPEDANCE BRIDGES. 4-page Catalog Sheet C-16 gives complete specifications and operating data on Model 250 series universal impedance bridges.—Electro Measurements, Inc., 7524 S. W. Macadam Ave., Portland 19, Ore.

CIRCLE 331 ON READER-SERVICE CARD

VOLTAGE DIVIDERS. 4-page Catalog Sheet C-23 illustrates and describes voltage dividers with applications.—Electro-Measurements, Inc., 7524 S.W. Macadam Ave., Portland 19, Ore.

CIRCLE 332 ON READER-SERVICE CARD

ELECTRICAL, ELECTRONIC COMPONENTS

VERTICAL SENSING ELEMENT. 2-page Advance Technical Data Sheet describes and specifies an electrolytic sensing element which can be applied to any vertical sensing situation requiring an electrical output.—Kearfott Co., Inc., 1500 Main Ave., Clifton, N. J.

CIRCLE 333 ON READER-SERVICE CARD

CONTROLLABLE INDUCTOR. 4-page issue No. 5 of "Increductor Notes" describes electronically tuned receivers and discusses Increductor control circuits.—CGS Labs., Inc., Wilton, Conn.

CIRCLE 334 ON READER-SERVICE CARD

INDUSTRIAL ELECTRONICS. 400-page Catalog 70 lists, illustrates, and prices hundreds of electronics items from actuators to zipper tubing.—Newark Electric Co., 223 W. Madison St., Chicago 6, Ill.

CIRCLE 335 ON READER-SERVICE CARD

SOLDER TERMINALS. Wall chart shows dimensional sketches of 60 solder terminals in actual size.—Cambridge Thermionic Corp., 445 Concord Ave., Cambridge 38, Mass.

CIRCLE 336 ON READER-SERVICE CARD

METAL HOUSINGS. 20-page Catalog 600 illustrates and describes consoles, racks, cabinets, chassis, and panels for the electronics industry.—Premier Metal Products Co., 337 Manida St., New York 59, N. Y.

CIRCLE 337 ON READER-SERVICE CARD

SERVO-DRIVEN POTENTIOMETER. 2-page Bulletin 801 describes and specifies Model 801 servo-driven multi-output potentiometer.—Bourns, Inc., Box 2112, Riverside, Calif.

CIRCLE 338 ON READER-SERVICE CARD

TEST DATA. 16-page certified Test Report T-245 contains data covering Series 50 Helitrim trimming potentiometers.—Helipot Div. of Beckman Instruments, Inc., 2500 Fullerton Rd., Fullerton, Calif.

CIRCLE 339 ON READER-SERVICE CARD

MISCELLANEOUS

RECORDING ANNUNCIATOR. 4-page Bulletin 102A illustrates and describes Panalarm recording annunciator.—Panellit, Inc., 7401 No. Hamlin Ave., Skokie, Ill.

CIRCLE 340 ON READER-SERVICE CARD

HOT STRIP WIDTH GAGES. 4-page Bulletin 13-203 details equipment and operating principles of a new non-contact infrared-radiation-operated gage.—Daystrom-Weston Sales Div., 614 Frelinghuysen Ave., Newark 12, N. J.

CIRCLE 341 ON READER-SERVICE CARD

DRYERS. 4-page Bulletin 160-1 describes with illustrations and charts Hydryers dehydration units for air, gases, and liquids.—J. F. Pritchard & Co., 4625 Roanoke Parkway, Kansas City 12, Mo.

CIRCLE 342 ON READER-SERVICE CARD

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3	23	43	63	83	103	123	143	163	183	203	223	243	263	283	303	323	343				
4	24	44	64	84	104	124	144	164	184	204	224	244	264	284	304	324	344				
5	25	45	65	85	105	125	145	165	185	205	225	245	265	285	305	325	345				
6	26	46	66	86	106	126	146	166	186	206	226	246	266	286	306	326	346				
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18	38	58	78	98	118	138	158	178	198	218	238	258	278	298	318	338					
19	39	59	79	99	119	139	159	179	199	219	239	259	279	299	319	339					
20	40	60	80	100	120	140	160	180	200	220	240	260	280	300	320	340					

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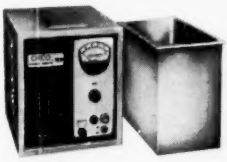

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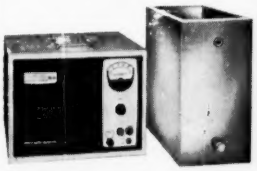

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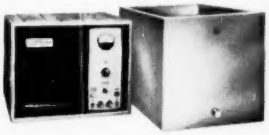

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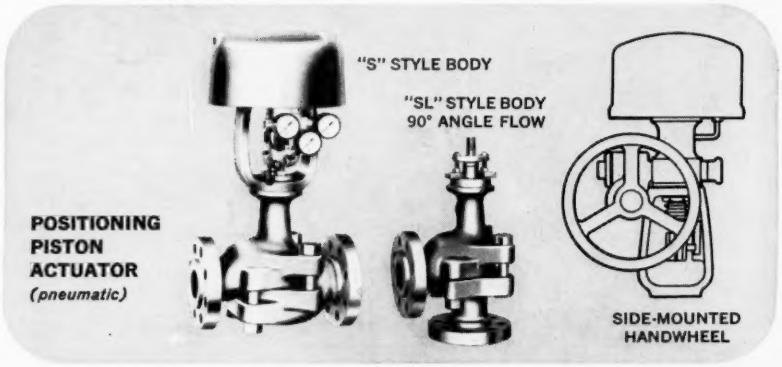

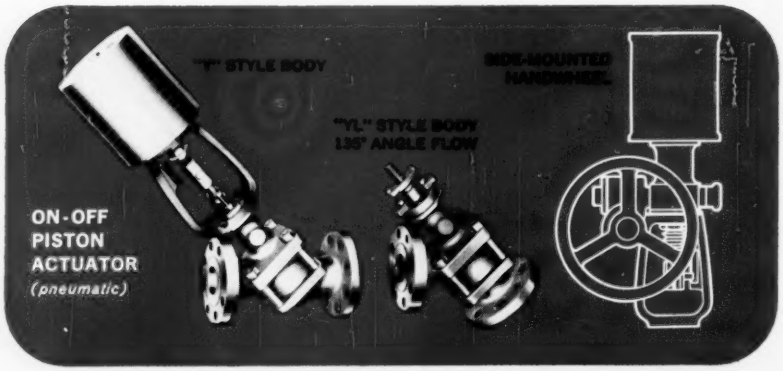

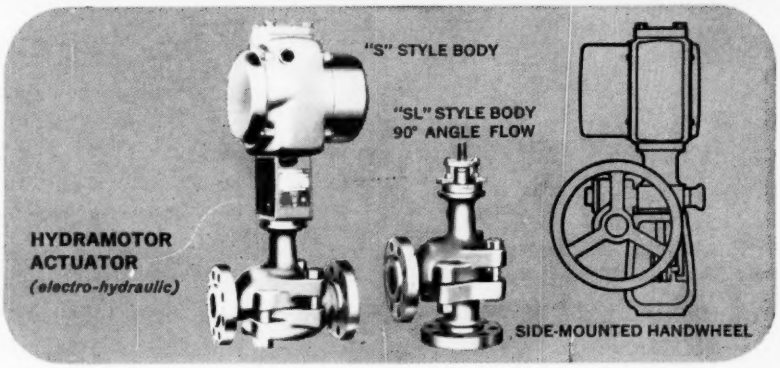

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